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An analysis of surface waves generated by a submerged hydrofoil

Jones, Cowan E.; Brooks, Wharton H.

Massachusetts Institute of Technology

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AN ANALYSIS OF SURFACE WAVES
GENERATED BY A SUBMERGED HYDROFOIL

C. E. JONES, JR.
AND
W. H. BROOKS, JR.

1953

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AN ANALYSIS OF SURFACE WAVES
GENERATED BY A SUBMERGED
HYDROFOIL

By

Cowan E. Jones, Jr.
Lieutenant^U, U.S. Navy

Wharton H. Brooks, Jr.
Lieutenant (Junior Grade), U.S. Navy
B.S., U.S. Naval Academy, 1947

Submitted in partial fulfillment of
the requirements for the degree of

NAVAL ENGINEER

From the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

(1953)

ABSTRACT

TITLE: An Analysis of Surface Waves Generated by a Submerged Hydrofoil.

AUTHORS: Lieutenant Cowan E. Jones, Jr., U. S. Navy
Lieutenant (Junior Grade) Wharton H. Brooks, Jr.,
U. S. Navy

Submitted to the Department of Naval Architecture and Marine Engineering on 25 May 1953 in partial fulfillment of the requirements for the degree of Naval Engineer.

This investigation is a study of the characteristics of the surface wave generated by a submerged hydrofoil.

The experimentation is conducted on essentially a two-dimensional basis. Measurements were taken along the centerline of a circulating water channel. The wave generator is an infinite aspect-ratio foil of NACA 4412 designation. Generated under controlled conditions of hydrofoil angle of attack, depth of submergence, and stream velocity, the wave is defined by measurements of basic dimensions such as amplitude and wave length.

Results obtained are:

1. $\lambda = \frac{2\pi v^2}{g}$ as predicted by theory.
2. Curves expressing the relationship: amplitude versus angle of attack, submergence and velocity.

It is concluded that deep water waves can be simulated in a circulating water channel. An extension of the range of this type of experimentation can lead to a complete solution to the characteristics of surface waves generated by a submerged hydrofoil.

Cambridge, Massachusetts
25 May, 1953

Secretary of the Faculty,
Massachusetts Institute of Technology,
Cambridge, Massachusetts.

Dear Sir:

In accordance with the requirements for the degree of
Naval Engineer, we submit herewith a thesis entitled "An
Analysis of Surface Waves Generated by a Submerged Hydro-
foil."

Respectfully,

NOTATION

- a. Wave amplitude.
- C. Chord-length of hydrofoil.
- d₀ Depth of the stream in the flume.
- d₁ Depth of submersion of the hydrofoil,
measured from the surface to the tip of the leading edge.
- Fr. Froude no. of the flume $\frac{V}{\sqrt{gd_0}}$.
- Fr. Froude no. of the hydrofoil $\frac{V}{\sqrt{gc}}$.
- H. Manometer head (feet)
- L. Width of flume.
- Q. Flow rate of the flume (cubic feet/second).
- V. Velocity of flow (feet/second).
- α . Angle of attack of the foil.
- λ . Wave-length.
- l₁ Horizontal distance from the hydrofoil leading edge to the
first wave hollow.
- l₂ Horizontal distance from the hydrofoil leading edge to the
first wave crest.
- y₀ The vertical distance between the undisturbed stream surface
and the first wave hollow.
- y₁ The vertical distance from the undisturbed stream surface
to the peak of the wave formed above the front of the
foil (when occurring).

NOTES

1. Two points.
2. Two points at right angles.
3. Right of the system in the line.
4. Right of connection of the hydraulic system from the surface to the lip of the landing edge.
5. $\frac{V}{g}$ Right no. of the line.
6. $\frac{V}{g}$ Right no. of the hydraulic system.
7. Distance from (left).
8. Right of line.
9. Right no. of the line (under load/weight).
10. Right of line (load/weight).
11. Right of weight of the line.
12. Two points.
13. Horizontal distance from the hydraulic landing edge to the line from center.
14. Horizontal distance from the hydraulic landing edge to the line from center.
15. The vertical distance between the horizontal ground surface and the first curve.
16. The vertical distance from the horizontal ground surface to the point of the curve above the line of the line (from center).

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xliv	XLIV
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xlvix	XLIX
l	L
li	LI
lii	LI
liii	LII
liv	LIII
lv	LIV
lvi	LVI
lvii	LVII
lviii	LVIII
lvix	LIX
lx	LX
lxi	LXI
lxii	LXII
lxiii	LXIII
lxiv	LXIV
lxv	LXV
lxvi	LXVI
lxvii	LXVII
lxviii	LXVIII
lxvix	LXIX
lxx	LXX
lxxi	LXXI
lxxii	LXXII
lxxiii	LXXIII
lxxiv	LXXIV
lxxv	LXXV
lxxvi	LXXVI
lxxvii	LXXVII
lxxviii	LXXVIII
lxxvix	LXXIX
lxxx	LXXX
lxxxi	LXXXI
lxxxii	LXXXII
lxxxiii	LXXXIII
lxxxiv	LXXXIV
lxxxv	LXXXV
lxxxvi	LXXXVI
lxxxvii	LXXXVII
lxxxviii	LXXXVIII
lxxxvix	LXXXIX
lxxxx	LXXXX
lxxxxi	LXXXXI
lxxxxii	LXXXXII
lxxxxiii	LXXXXIII
lxxxxiv	LXXXXIV
lxxxxv	LXXXXV
lxxxxvi	LXXXXVI
lxxxxvii	LXXXXVII
lxxxxviii	LXXXXVIII
lxxxxvix	LXXXXIX
lxxxxx	LXXXXX

I. INTRODUCTION

The use of hydrofoils attached to the hull of a surface vessel is not a new idea. Their application has been attempted in many ways. In the latter part of the last century, Alexander Graham Bell designed a small high-speed craft equipped with foils which attained remarkable speeds for the power then installed. During World War I, the British Admiralty investigated the possibility of using foils on ships with the idea of lifting a ship bodily out of the water to reduce its susceptibility to torpedo attack, but investigations were abandoned without conclusive results.

The Denny-Brown Stabilizer, which was first introduced commercially in the 1920s, represents a successful application of hydrofoils on surface vessels. The stabilizer consists of a hydrofoil located on each side of a vessel's hull at the turn of the bilge. The hydrofoils are actuated by machinery within the ship which causes them to rotate to counteract and reduce the roll of the vessel in a seaway.

For the past fifteen years hydrofoils for use on high-speed surface craft have become increasingly popular. However, their use has been restricted to very small high-speed craft whose displacement is small enough to permit the foils to lift the craft out of the water. With the exception of the Denny-Brown Stabilizers, no real attempt has been made to apply hydrofoils to large ships.

The attachment of hydrofoils to a ship's hull for the purpose

of reducing wave resistance is a comparatively new idea. In a recent paper, read before the 1953 meeting of the Society of Naval Architects and Marine Engineers, Professor M. A. Abkowitz of M.I.T. presented his ideas and the results of his experiments showing the possibility of reducing the wave resistance of ships by the use of hydrofoils located at the forefoot. Under Professor Abkowitz's supervision, towing tank model experiments have been conducted which have shown qualitatively a decrease of model resistance at high speeds.

The objective of this use of hydrofoils is to achieve a net decrease in resistance by accepting increased frictional resistance in return for a large reduction of wave making resistance.

Wave resistance can be considered essentially a pressure phenomenon in which the pressure gradient around a body moving near or on the free surface of a fluid results in the formation of a system of gravity waves. The most prominent, in the case of a surface hull of large displacement, is the bow wave. A reduction in the amplitude of the generated waves by means of a hydrofoil attached to the hull represents a lower energy loss from the moving vessel, which may result in an increase in speed or a reduction in the required horsepower for a proposed design. The presence of a hydrofoil in the vicinity of a vessel's bow, so located that its generated wave system would partially cancel the ship's generated waves (particularly the bow wave), could reduce the wave making resistance of the vessel. Furthermore, as a secondary advantage, this device, by its very location, has the useful characteristic of reducing the pitching of a vessel in a seaway.

of resistance was resistance in a comparatively low form. In a
second paper, read before the 1953 meeting of the Society at New
York, the author, Professor A. I. Lohr, of M.I.T.,
presented his ideas on the basis of his experiments showing the
possibility of reducing the wave resistance of ships by the use of
hydrofoil devices at the bottom of the hull. Under Professor Lohr's
experimental work, such hydrofoil devices have been shown to be
very effective in reducing the wave resistance of ships.
The object of this use of hydrofoils is to reduce the wave
resistance of ships by attaching hydrofoil devices to the
bottom of a ship's hull to reduce resistance.
This resistance can be reduced essentially a great amount
and in doing the hydrofoil device is a very important part of the
the new system of a hull device to the reduction of a ship's
wave resistance. For each problem, on the case of a surface will be
large displacement, in the low form. A reduction in the resistance of
the hydrofoil device is made at a hydrofoil attached to the hull of a
ship. A great amount of energy from the water vessel, which may result
in an increase in speed on a hull in the reduced resistance for
a reduced form. The purpose of a hydrofoil is to reduce the
wave resistance of a ship, and in doing this the hydrofoil device would
likely reduce the ship's resistance (mainly the wave resistance).
The hydrofoil device, being attached to the hull of the vessel, functions
as a hydrofoil device, the device for the hull of the vessel, and the
hydrofoil device is attached to the hull of a vessel in a

Once the form of the hydrofoil has been decided upon, the problem of locating it with respect to the fluid is to achieve optimum wave position as readily practicable. It is therefore necessary that the characteristics of a hydrofoil operating near the surface of a fluid be available. The purpose of this investigation is to analyze the behavior of a typical hydrofoil and determine its characteristics. In a literature survey conducted by the authors, it became evident that information pertaining to hydrofoil characteristics in producing surface waves was not available. Certain work has been done in regard to the analysis of surface waves generated by a few geometrical shapes (principally bodies of revolution) and the general characteristics of surface waves have been theoretically defined. However, no work has been done on hydrofoils. Therefore, it was decided to examine the characteristics of a wave system generated by a particular hydrofoil, operating at various angles of attack, velocities, and depths of submergence.

Attempts to analyze wave generation by hydrofoils previously had been made in the towing tank at M.I.T., but the results indicated that a towing carriage rather than the installed towing-wire would be necessary for extensive study. The best method available appeared to be a two-dimensional analysis in the circulating water channel installed in the Hydrodynamic Laboratory at M.I.T.

The first of these is the fact that the system is not a simple one. It is a complex one, and it is one that is not easily understood. The second is the fact that the system is not a simple one. It is a complex one, and it is one that is not easily understood. The third is the fact that the system is not a simple one. It is a complex one, and it is one that is not easily understood. The fourth is the fact that the system is not a simple one. It is a complex one, and it is one that is not easily understood. The fifth is the fact that the system is not a simple one. It is a complex one, and it is one that is not easily understood. The sixth is the fact that the system is not a simple one. It is a complex one, and it is one that is not easily understood. The seventh is the fact that the system is not a simple one. It is a complex one, and it is one that is not easily understood. The eighth is the fact that the system is not a simple one. It is a complex one, and it is one that is not easily understood. The ninth is the fact that the system is not a simple one. It is a complex one, and it is one that is not easily understood. The tenth is the fact that the system is not a simple one. It is a complex one, and it is one that is not easily understood.

II PROCEDURE

The wave profile was obtained by running a centerline traverse the length of the test section. The surface elevation at each point was obtained by the point gage; the horizontal distances were fixed by alignment of the telescope cross hairs on the probe tip and reading of location on the scale affixed to the telescope bench. The location of the probe tip may be measured to 0.01 centimeter with such a point gage, and the telescope location read to .02 inches. The instrumentation, simple as it may seem, is very precise in comparison to the inherent fluctuation in a circulating water channel.

The profile points were taken at intervals consistent with the wave length and amplitude, and the curve fixed by these points was the basic result of each run. Because of the large number of runs necessary, averaging of several readings of surface elevation at each point was not feasible. The averaging was done by eye, and only one reading obtained at each point. To avoid errors in instrument reading, profile points were plotted as they were obtained, and examination of the resulting curves showed that this method gave sufficient precision, (see sample profiles appendix C).

In conducting the runs, velocity (V), angle of attack (α), depth of submergence (d_1) and total depth of flow (d_0) were controllable.

To analyze the resulting wave, three types of flow were considered, 1) approach flow, 2) transition zone, 3) steady state wave formed after transition. Wave length of the steady state portion (λ),

II. Discussion

The wave profile was obtained by running a computer program and length of the last section. The surface elevation at each point was obtained by the point gauge; the horizontal distance was fixed by alignment of the reference cross hairs on the ground and water. The location of the gauge was fixed to the reference cross hairs. The location of the gauge was measured to 0.01 centimeter with a point gauge, and the reference location was to 0.01 inches. The instrumentation, which is a very precise in comparison to the standard instrumentation in a laboratory water channel.

The profile points were taken at intervals consistent with the wave length and wavelength, and the curve fitted to these points was the basic result of each run. Because of the large number of runs necessary, averaging of several readings of surface elevation at each point was not feasible. The averaging was done up to 10, and only one reading obtained at each point. In order to avoid errors in the stream reading, profile points were divided as they were obtained, and estimated of the resulting curve showed that this method gave sufficient precision. Two angles, relative to the wave, in conducting the runs, namely (1) angle of attack (2) angle of observation (3) and (4) angle of flow (5) were maintained. In order to obtain the results, three types of flow were obtained: (1) approach flow; (2) transition flow; (3) wave flow were formed after transition. The location of the wave was given (4).

wave amplitude in the steady state region (a), and the characteristic dimensions of the transition region (y_0, y_1, l_1, l_2) comprised the data obtained from evaluation of the profiles.

Three types of run were taken, according to the data desired.

1) Full profile the length of the test section or to the point where instability of flow made measurements doubtful. From such a profile, all variables could be measured.

2) A profile from undisturbed approach flow through the transition zone, and surface elevation only of the steady state flow at maximum and minimum points. This yields all data except wave length and shape of the steady state portion.

3) Measurement of elevation of approach flow and of the maxima and minima in the steady state wave. This gives only amplitude of the steady wave.

Evaluation of Data.

Variables were obtained in the following manner.

Type 1 runs) " λ " and " a " represent an average of all steady state waves obtained in each run. This, plus the averaging implicit in drawing a smooth curve through the plotted points, yielded reasonable, consistent results. For the parameters of the transition region, we have, of course, but one measurement per run. Fortunately, the transition zone, free from wall and side support effects, is highly stable, and profile measurements to the order of accuracy of the approach flow were obtainable.

Type 2 runs) " a " is the difference of the averages of maxima and minima. The transition zone is evaluated as in type 1 runs.

Type 3 runs) "a" only is evaluated and is, as before, the difference of the averages of maxima and minima.

Total 7 items

distance of the system of the system

III RESULTS

1. There is no measurable damping present over the length of the test section or any discernable damping to the point where weir overfall occurs. As high as ten wave-lengths were observed with no apparent change of amplitude or wave-length.

2. It is possible to simulate deep water effects in a circulatory water channel. See Figure XIII.

3. There is no rise of the surface above the foil section at submergences greater than .95 C.

4. There is no effect on approach flow more than one chord-length ahead of the foil.

5. The theoretical relation

$$\lambda = \frac{2 \pi v^2}{g} \quad (1)$$

is confirmed. A plot of this is shown in Figure II.

6. Curves of α/c versus R , at various angles of attack.

7. Curves of α/c versus d_1/c at various Froude numbers and angles of attack.

8. The following numerical averages and range of variations from these averages were found relating the transition zone to the steady wave:

	y_0/a	L_1/λ	L_2/λ
Avg.	.533	.50	1.04
Min.	.44	.46	0.95
Max.	.67	.54	1.14

CHAPTER III

1. There is no considerable change present over the length of the test section in any dimension leading to the point where with overall average. It also as the wave-lengths were observed with an average change of amplitude of wave-length.

2. It is possible to observe deep water effects in a dip-

olegical water channel. See figure XIII.

3. There is no rise of the surface above the full section

at subsequent greater than 1.5 ft.

4. There is no effect on approach flow more than one eleph-

antical wave of the flow.

5. The theoretical relation

$$(1) \quad \lambda = \frac{2\pi V^2}{g}$$

is confirmed. A plot of λ vs V^2 is shown in figure II.

6. Curves of λ/V^2 vs V^2 at various angles of attack.

7. Curves of λ/V^2 vs V^2 at various wave heights and

angles of attack.

8. The following numerical averages and range of variations from these averages were found regarding the position and the

shape wave:

λ/V^2	λ/V^2	λ/V^2	
1.12	1.81	1.12	avg.
0.95	0.86	1.16	min.
1.24	1.74	0.97	max.

VARIATION OF WAVE-LENGTH WITH TOTAL DEPTH OF WATER

$\alpha = 2^\circ$ $d_1 = 1.06C$
M.I.T. 25 MAY 1953
C.E. JONES, JR.
W.H. BROOKS, JR.

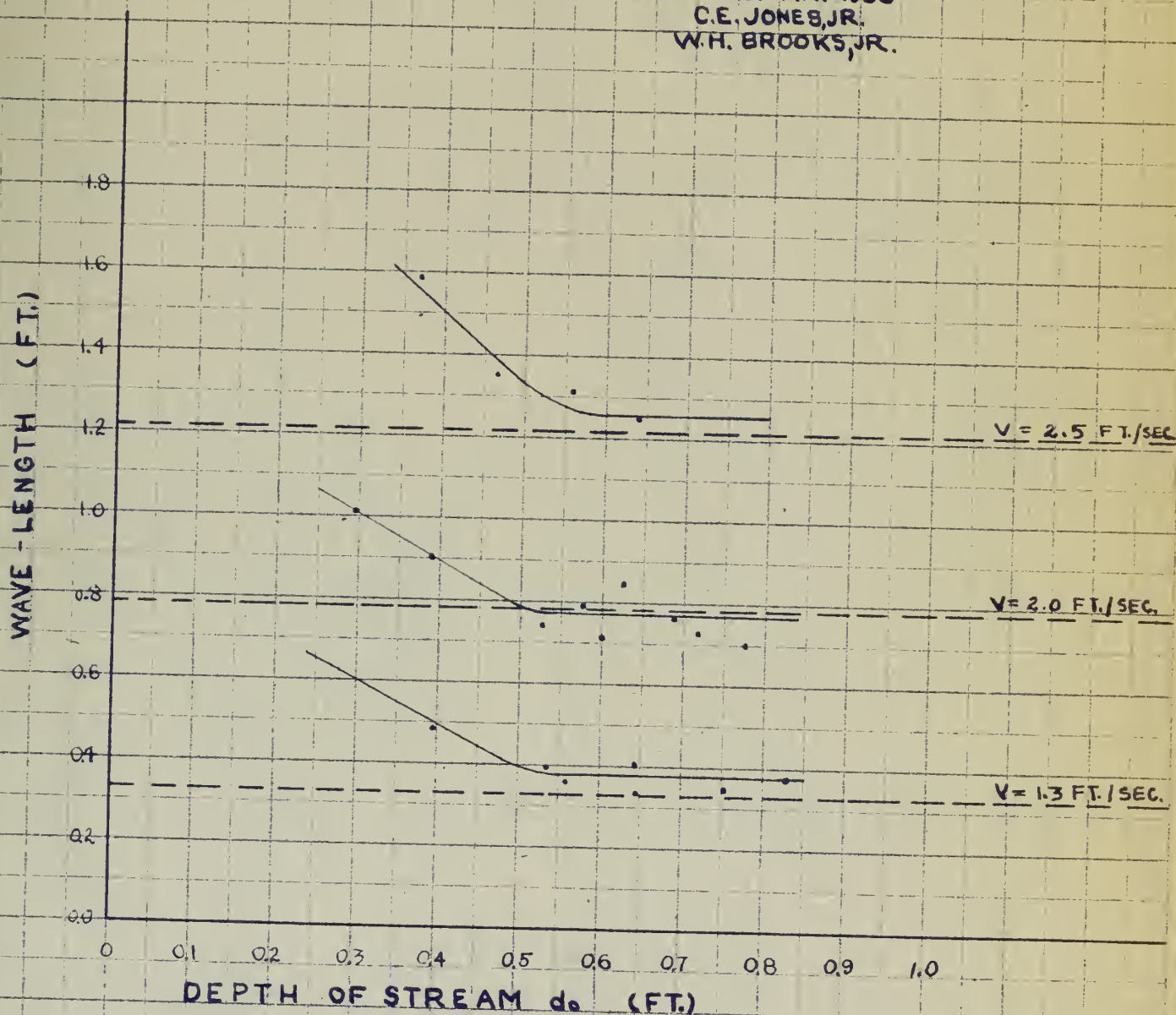
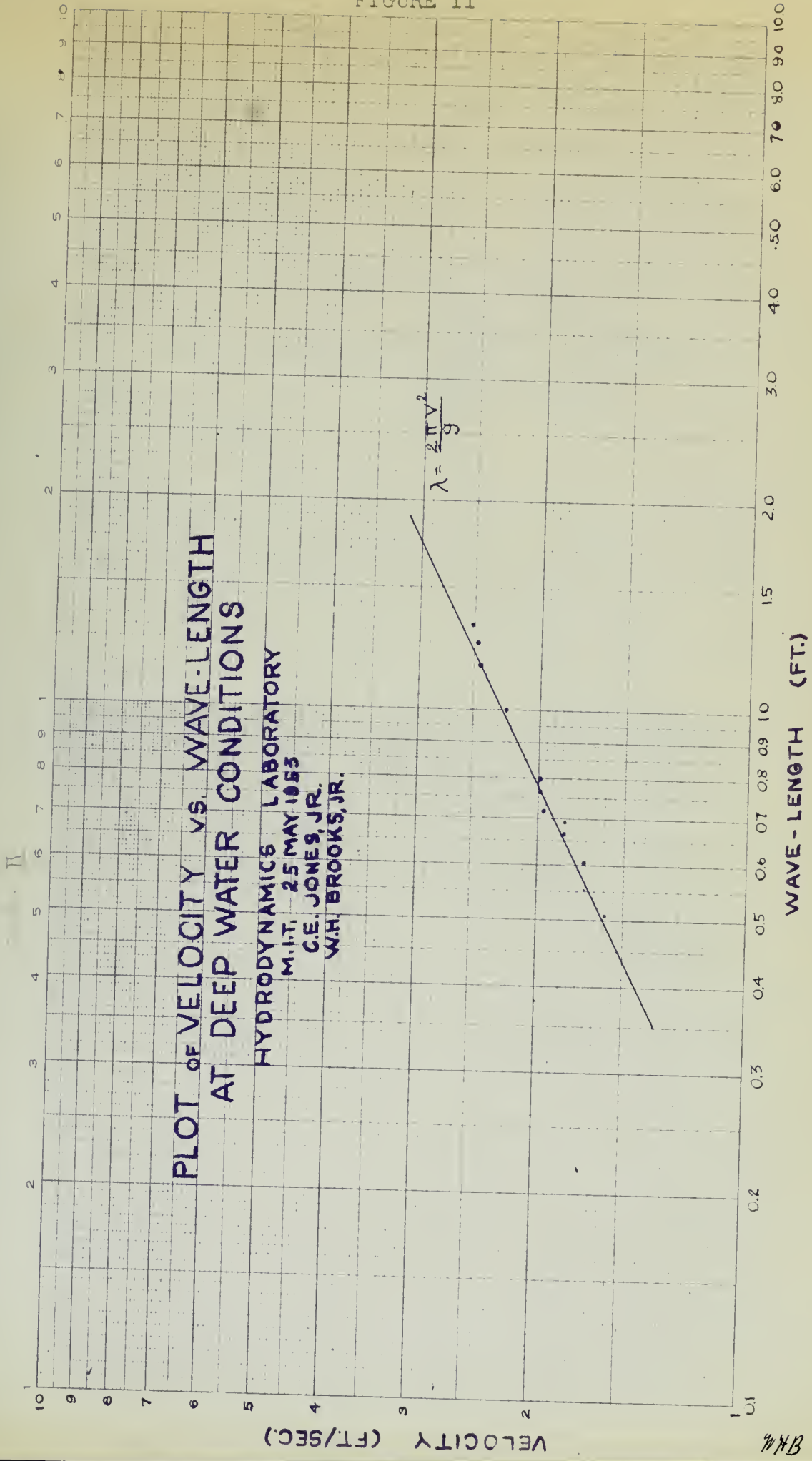
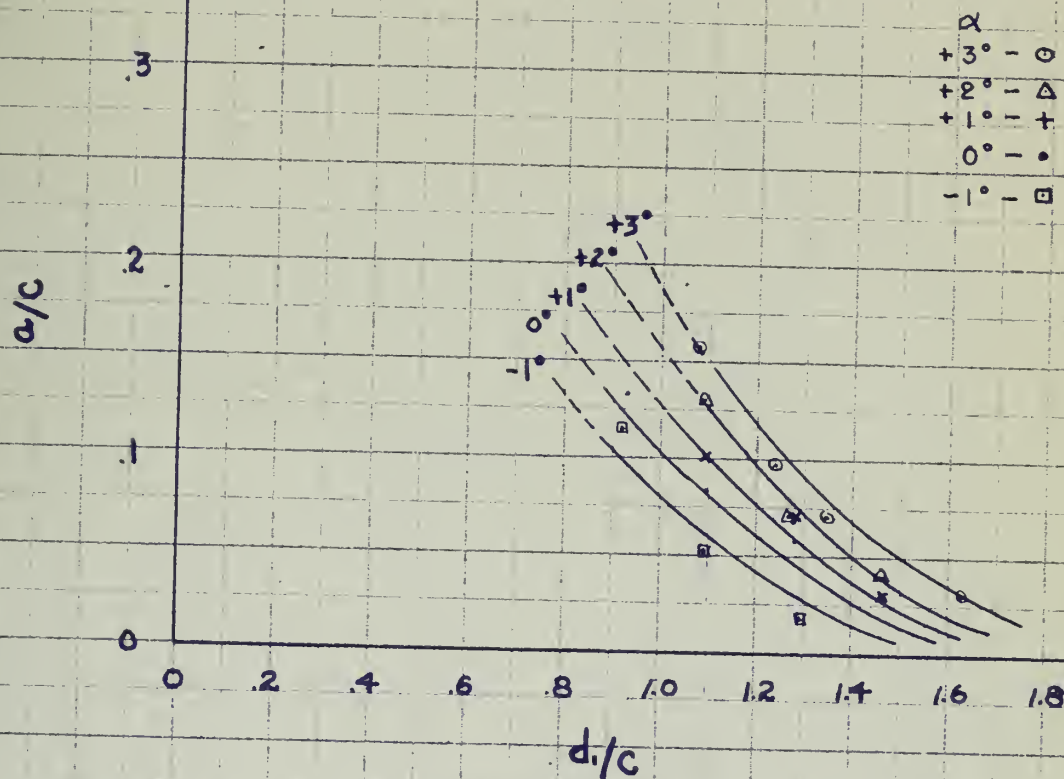


FIGURE II

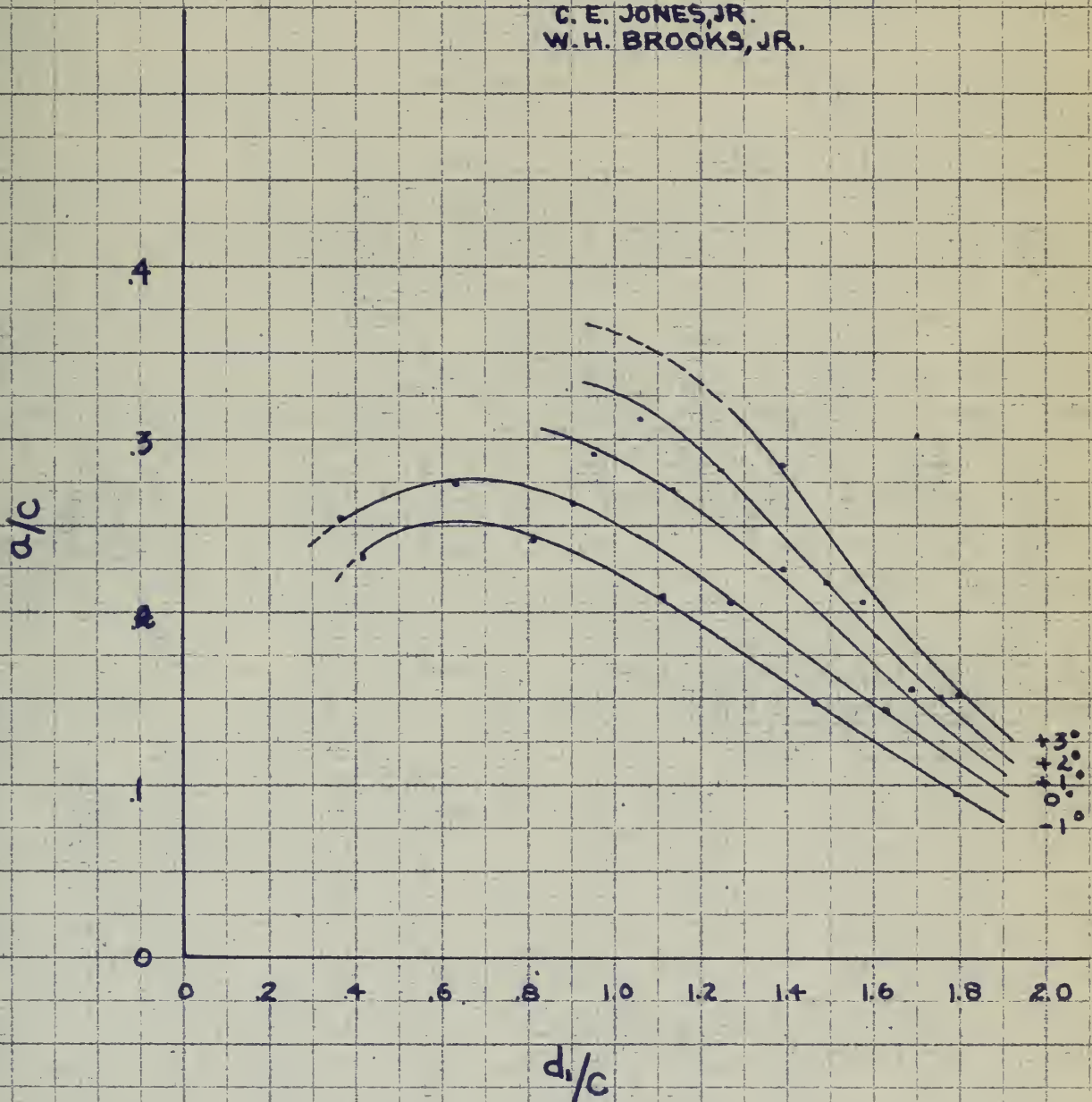


BMA cef

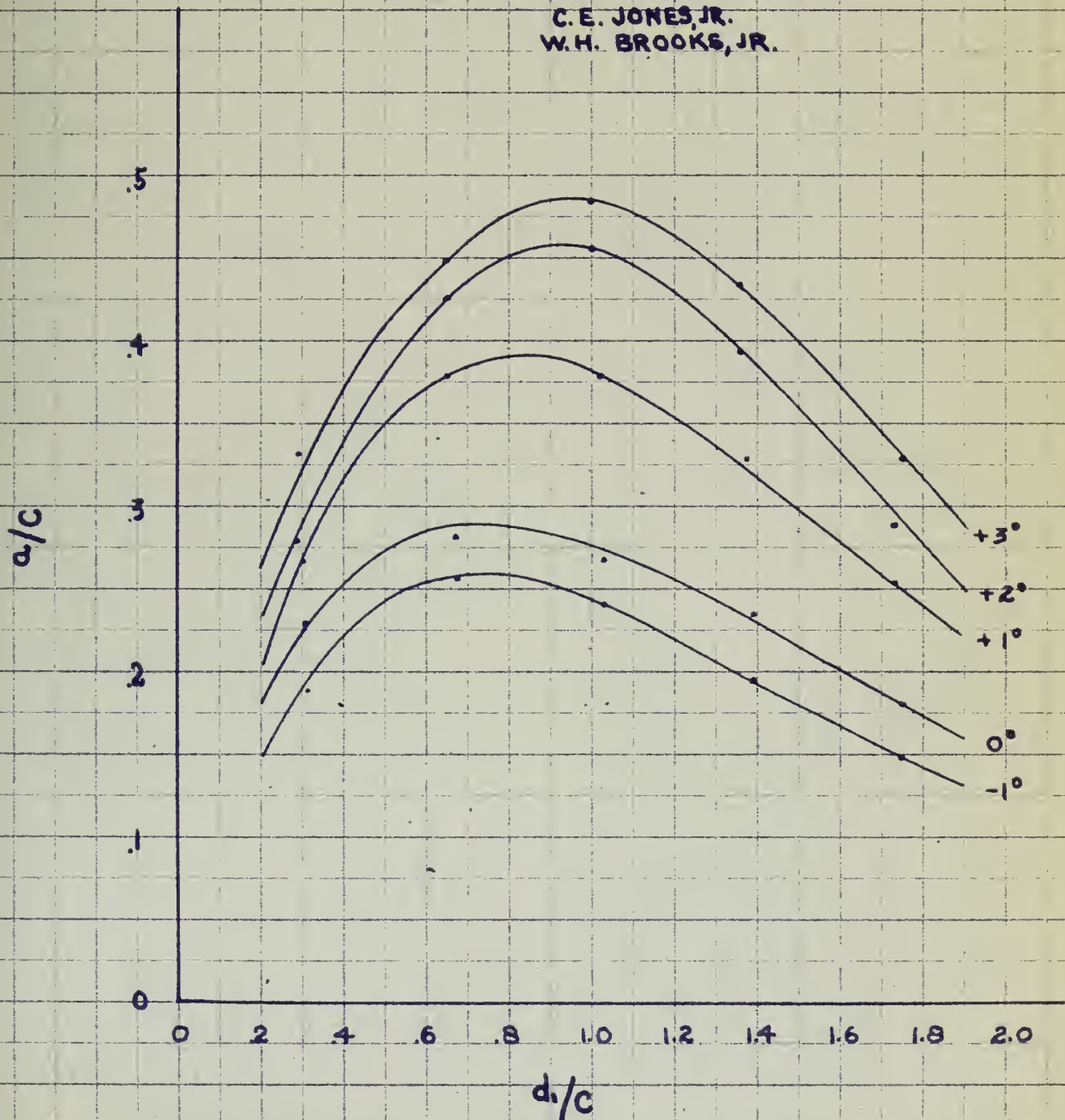
PLOT OF a/c vs. d/c
 AT $Re = .550$
 AT VARIOUS ANGLES OF ATTACK
 C. E. JONES, JR.
 W. H. BROOKS, JR.



PLOT OF a/c vs. d_1/c
 AT $Re = .733$
 AT VARIOUS ANGLES OF ATTACK
 C. E. JONES, JR.
 W. H. BROOKS, JR.



PLOT OF a/c vs. d_1/c
AT $R_1 = .920$
AT VARIOUS ANGLES OF ATTACK
C.E. JONES, JR.
W.H. BROOKS, JR.

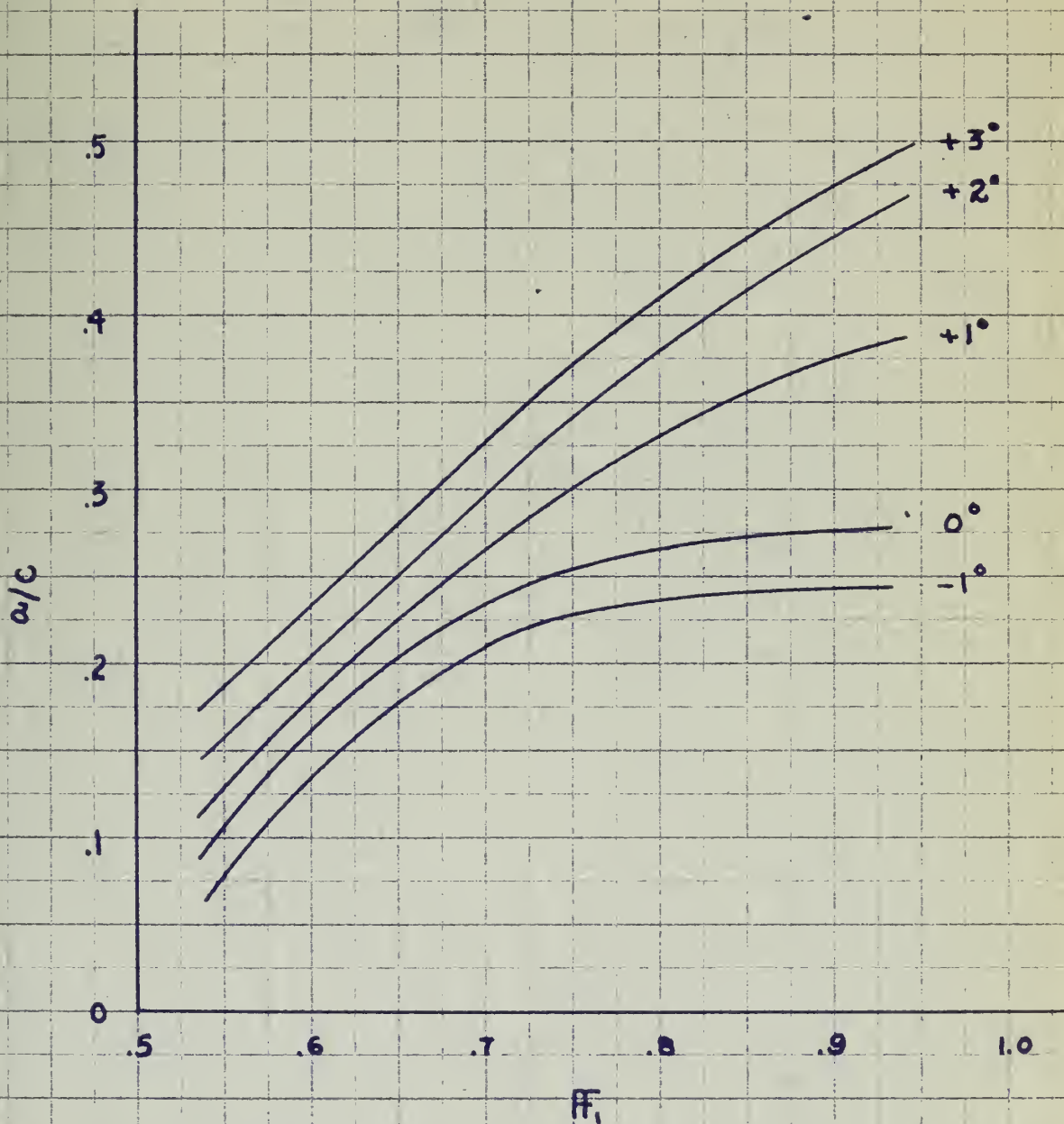


25 MAY 1953

CEJ

W/HB

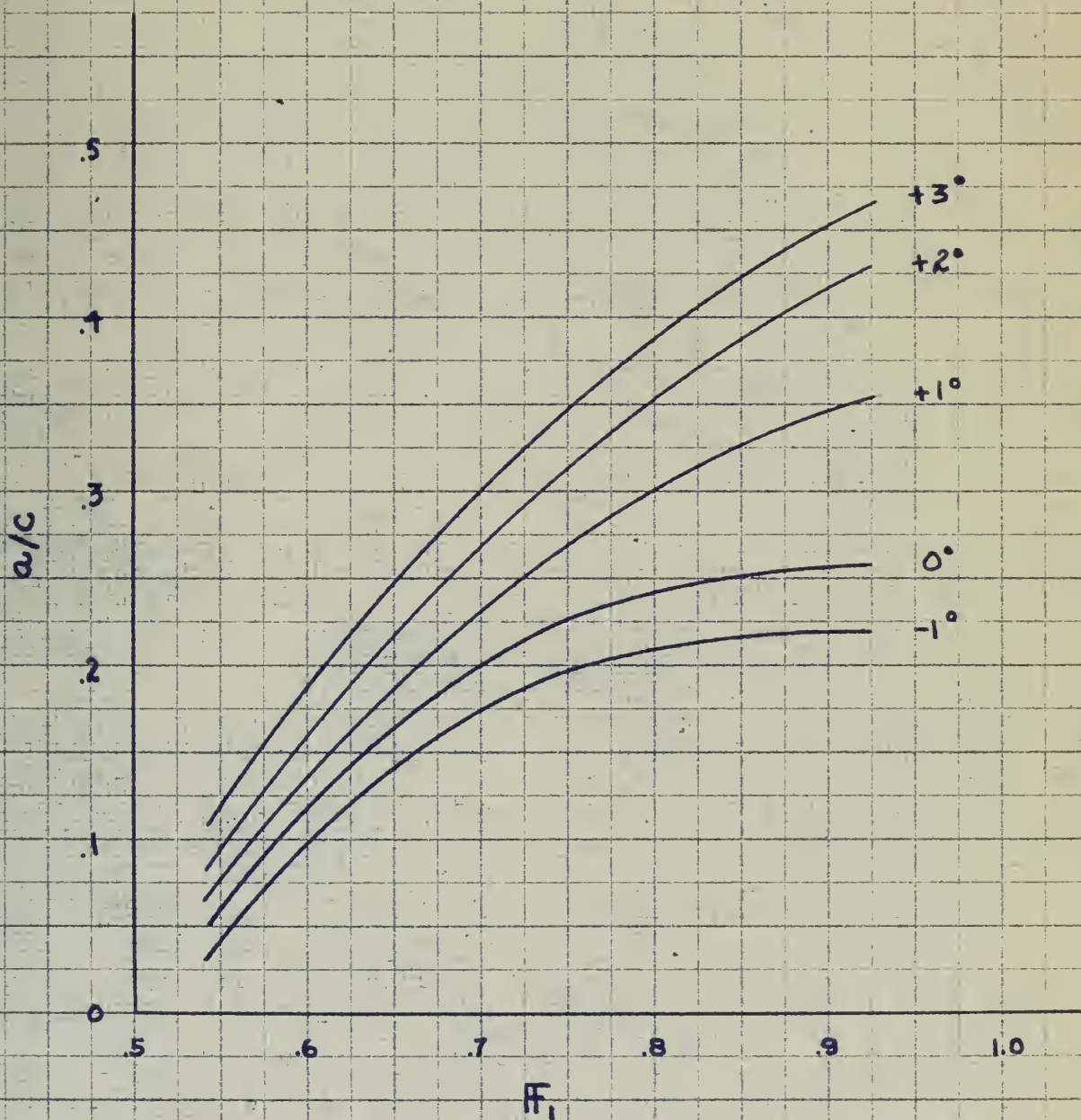
PLOT OF α/c VS F_1
AT A DEPTH OF SUBMERGENCE
OF 1.0 C
AT VARIOUS ANGLES OF ATTACK
C.E. JONES, JR.
W.H. BROOKS, JR.



25 MAY 1953

CEJ WNB

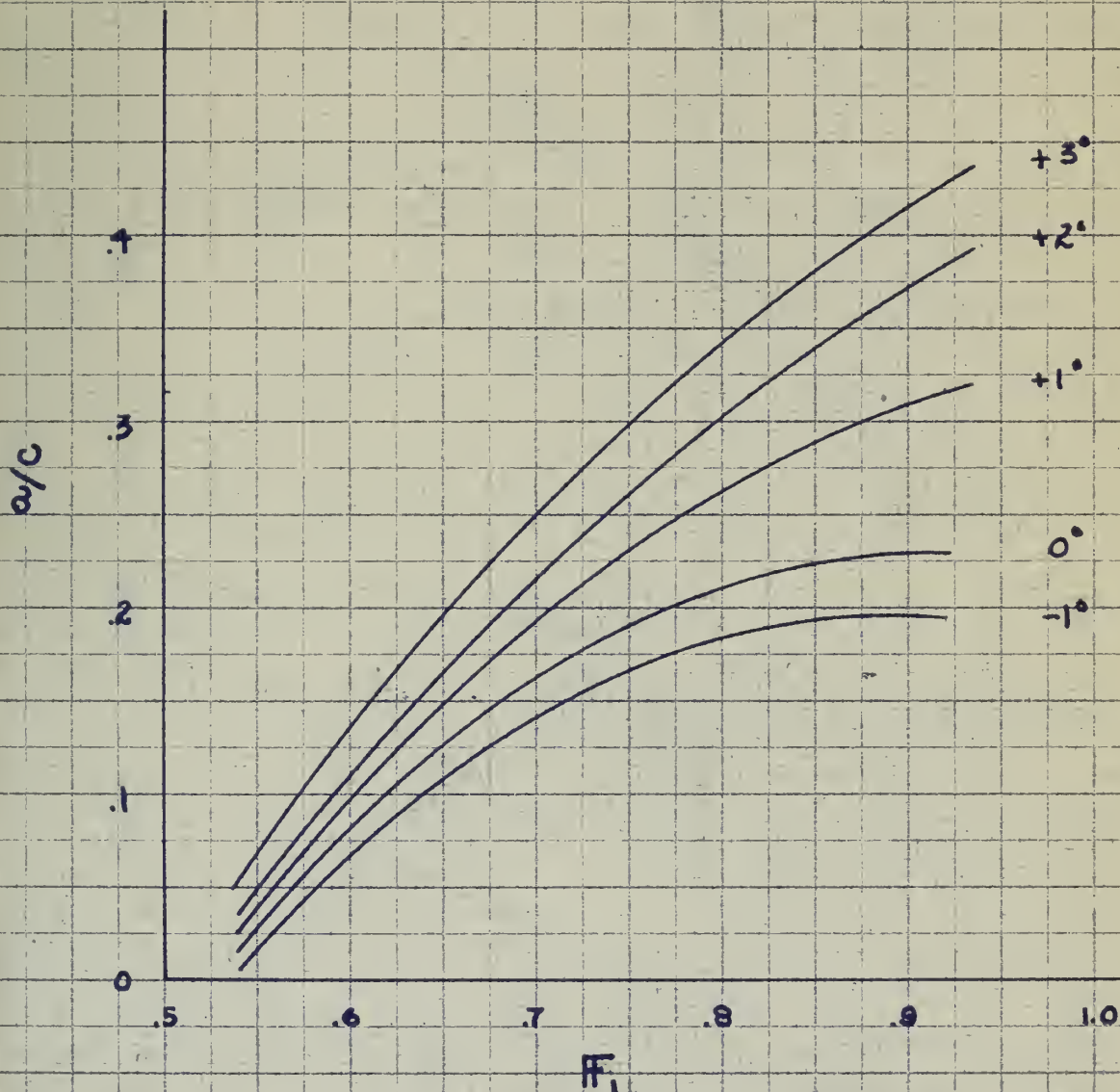
PLOT OF a/c vs. H_1
AT A DEPTH OF SUBMERGENCE
OF 1.2 C
AT VARIOUS ANGLES OF ATTACK
C. E. JONES, JR.
W. H. BROOKS, JR.



25 MAY 1953

CEJ WNB

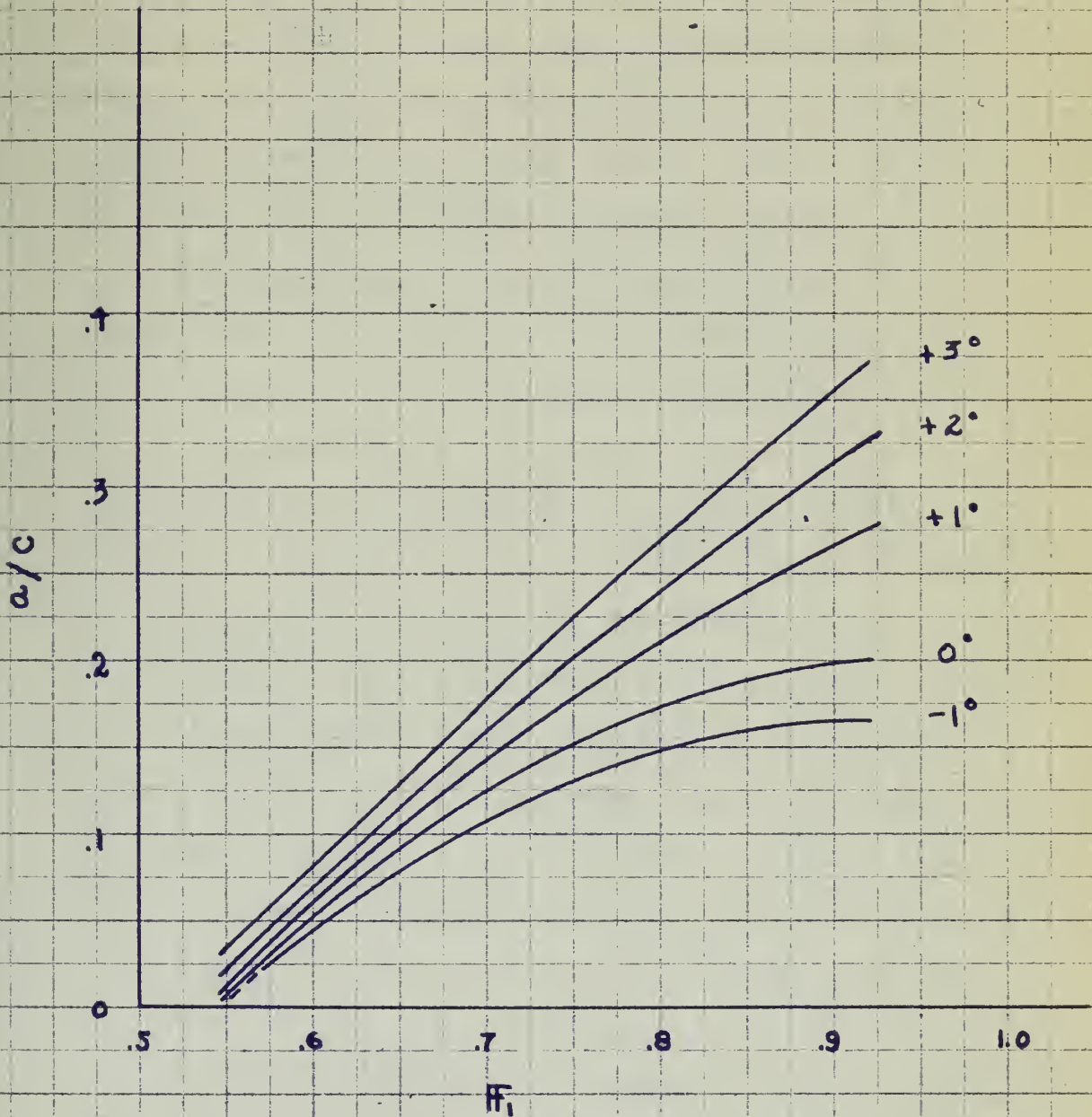
PLOT OF α/c vs. Fr
AT A DEPTH OF SUBMERGENCE
OF 1.4 C
AT VARIOUS ANGLES OF ATTACK
C. E. JONES, JR.
W. H. BROOKS, JR.



25 MAY 1963

CEJ WAB

PLOT OF a/c VS. F_1
AT A DEPTH OF SUBMERGENCE
OF 1.6 C
AT VARIOUS ANGLES OF ATTACK
C.E. JONES, JR.
W.H. BROOKS, JR.



25 MAY 1963

CEJ WNB

IV DISCUSSION OF RESULTS

The object of this research was to find the change in the resulting wave pattern with changes in the conditions of the wave generating hydrofoil. In many cases, the relations were clearly defined and these have been expressed in the preceding section. In other instances (the parameters of the transition zone in particular), where such variations were not clearly defined, interpretation was needed. In these cases, we have made our interpretation and drawn our conclusions. For those who do not agree, the table, Summary of Data, found in appendix B, must comprise the results. It is hoped that sufficient information is expressed therein to aid the research of those individuals interested in hydrofoils.

Since this work was attempted with a view toward the use of hydrofoils in suppression of the wave train of a surface ship, it will be evaluated and interpreted primarily on this basis.

Not previously mentioned in this paper are the serious limitations imposed by the equipment which was used. Principal among them was an overall limitation on range of both velocity and total depth. At the present time, hydrofoils used as wave suppressors have been of chord-length equal to or greater than the draft of the ship model tested. This would mean, in full scale terms, that a destroyer type vessel, operating at a speed of about thirty knots, and using a foil with chord-length of about fifteen feet would give a Froude number on the foil (V/\sqrt{gc}) of about 2.3.

[illegible]

For a typical merchant vessel with a speed of about twenty knots, using a chord-length of twenty feet, the hydrofoil's Froude number might be 1.3. In our test range, the maximum Froude number attained for the foil was 0.92.

This means that the range of experimentation may not allow direct scaling of the results of these tests to a full size ship. This limit was recognized early in the preliminary analysis, and the use of three sizes of foils of about one, two, and three inches was planned. Manufacturing difficulties prevented the use of more than one foil. It is to be noted that the original proposal would have extended the range of Froude number to a value of 1.7. The extension of the range of Froude numbers tested is recommended in order that the scaling methods of ship model testing may be directly applied.

The use of a range of sizes of foils would also have permitted examination of one more variable, chord-length, and would have allowed a check on the validity of the use of Froude number for a body which does not penetrate the surface. Only limited work has been done on this aspect, but it appears that this is the valid scale factor within the limiting assumptions accepted in ship model testing.

Unfortunately, this work makes no contribution to the problem of determining the shape of surface waves. Attempted analysis of wave shape by numerical methods⁽³⁾ proved unsuccessful. Thus, within the frame of characteristic dimensions presented here, the investigator or ship designer must choose which of the many pro-

posed theories he desires to use to express the shape of the wave.

No exact correlation of the characteristic dimensions of the transition was found. Examination of these dimensions indicates that their primary relation is to the respective dimensions of the steady state wave. In other words, ℓ_1 and ℓ_2 are increased by any change which increases λ , and y_0 is increased similarly with increases in "a". In the absence of any better correlation, numerical averages and the range of values obtained are presented. It should be noted that, for waves in which there was breaking of the crest of the first wave, the measured values of neither ℓ_2 or of "a" were usable in this analysis. This is easily explained; the breaker is a region of high energy dissipation which affects the energy content of the wave which follows the breaker. Also of interest may be the fact that the presence of a breaker tends to stabilize the wave which follows, and very good measurements of λ are possible.

During the observation of the hydro-dynamic behavior of the hydrofoil two important phenomena are noteworthy of mention. First, it was noted that within the velocity range of the investigation there was no perceptible influence on the upstream flow in front of the leading edge of the hydrofoil at distances greater than one chord-length. Second, it was noted that at shallow depths of submergence (d_1) a wave hump appeared above the leading edge of the hydrofoil. These two

phenomena are of importance to the ship designer if hydrofoils are to be used to reduce the wave making of a ship. The usefulness of the first phenomena is obvious in that the designer can rely on a free uninterrupted flow up a distance of one chord-length in front of the hydrofoil. The second phenomena, characterized by the dimension y_1 , is not clearly defined at the present time. Only one conclusion is drawn--namely that in no case does a hump appear until the depth of submergency (d_1) decreases below .95C. This fact is useful to the designer in that within the Froude number range of this investigation it indicates that the designer should not locate a hydrofoil at the bow of a ship closer than one chord-length to the surface. Otherwise the presence of the hump will tend to offset the wave reducing feature of the hydrofoil.

The results of this investigation show that not only can a flume be used to study the behavior of a hydrofoil in deep water but also that the shallow water effect can easily be discerned by noting variation in wave-lengths with stream depth at various stream velocities. The resulting curves showing this phenomena need no further amplification.

Fortunately, theory and previous experimental work are available with respect to wave length of a surface wave. That the accepted criteria of λ for waves travelling over the surface of a deep body of water was met in the experimental results is a verification of the proposition that deep water conditions can be simulated in a relatively shallow, circulating water channel.

phenomena are of importance to the ship designer. It is
not to be used to reduce the wave loading on a ship. The use-
fulness of the first phenomenon is shown in that the designer
can rely on a free undisturbed flow up to a distance of one ship-
length in front of the hydrofoil. The second phenomenon, however,
based on the assumption that it is not directly related to the present
time. Only one conclusion is drawn—namely that in no case does
a sharp square, with the depth of submergence (d) decreases below
1.75c. This limit is useful to the designer in that within the
range number range of 1.75c investigated it indicates that the
designer should not locate a hydrofoil at the bow of a ship closer
than one ship-length to the surface. Otherwise the presence of
the ship will tend to alter the wave reducing feature of the
hydrofoil.

The results of this investigation show that not only can a
flow be used to study the behavior of a hydrofoil in deep water
but also that the surface waves which are easily be disturbed by
smaller vessels in near-surface with almost depth of surface
stream velocity. The resulting waves showing this phenomenon must
be further explained.

Unfortunately, theory and previous experimental work are avail-
able with respect to wave height of a surface wave. The wave
height criteria of λ for waves travelling over the surface
of a deep body of water was not in the experimental results in
a realization of the proposition that deep water conditions can
be simulated on a relatively shallow, circulating water channel.

Since the generated waves are prone to be more unstable in horizontal location than in amplitude, an appreciable spread of experimental points about the mean line resulted.

With reference to wave stability, α/λ greater than 0.085 could not be achieved because of the breaking of the first wave crest. Following this stabilizing breaker α/λ values as high as 0.092 were achieved.

The relation of amplitude to submergence and angle of attack of the hydrofoil represents the primary result of this investigation. In the absence of comparative theory, the curves picturing this variation must be taken at the value indicated by the small deviations from the mean curves. These are design curves, and in addition lead to the following conclusion: for any angle of attack, there is an optimum depth which will produce the greatest amplitude of generated wave. This depth, in itself, is a function of the angle of attack, increasing with increased angle of attack in the manner shown by the curves of a/c vs. d_1/c at the various angles of attack.

This same information, plotted as a/c vs F_1 , is presented, since this form may well be more useful in design.

[illegible]

V CONCLUSIONS

1. This range of experimentation may not allow the results of these tests to be scaled directly to a full sized ship.
2. No clearly defined relationships for the transition region were found.
3. Bow hydrofoils should not be installed at depths of submergence of less than about one chord-length.

Y. LAMINATION

1. This range of lamination may not allow the results of these tests to be applied directly to a field study.
2. No directly related relationship for the lamination region were found.
3. The lamination should not be limited to depths of exposure of less than 1000 and 2000 ft.

VI RECOMMENDATIONS

1. Extension of the range of F_1 by similar tests to a value of approximately 2.5.

2. The use of geometrically similar foils of a different size to examine the variable, chord-length, and to check the validity of Froude Number as a scale factor.

Experimental Recommendations:

From observations and difficulties experienced, these recommendations are made for refinement of experimental techniques.

1. Insert false side walls in the flume to extend the velocity range and the depth of the flow. This would permit a better attachment of the hydrofoil to the sides and thus eliminate any "strut effect" which is set up by the side supports of the foil.

2. Install a fully adjustable weir gate to permit more precise control of velocity.

3. A more precise method for establishing angle of attack should be used. The present method, with the equipment used in this investigation, requires that the hydrofoil assembly be removed each time and set for a different angle of attack when so desired.

VI. DISCUSSION

1. Extension of the range of V_1 by similar cases of a value of approximately 2.2.
2. The use of potentially similar flows of a different size to examine the variables, characteristics, and to check the validity of results obtained at a single factor.
- Experimental observations are:
From observations and calculated relationships, these relationships are made for relationship of experimental relationships.
1. Lowest film side walls in the flow to extend the velocity range and the width of the flow. This would provide a better estimate of the hydrodynamic to the sides and some estimate of "side effect" which is set up by the side supports of the film.
2. Install a fully adjustable side wall to provide more precise control of velocity.
3. A more precise method for determining scale of attack should be used. The present method, with the adjustment used in this investigation, requires that the specimen be removed each time and set for a different scale of attack when so desired.

VII APPENDIX

CHAPTER IV

The first of the two main parts of the work is devoted to a study of the history of the English language from its earliest beginnings to the present day. The second part is devoted to a study of the English language as it is used in the present day. The first part is divided into two main sections: the first section is devoted to a study of the history of the English language from its earliest beginnings to the present day, and the second section is devoted to a study of the English language as it is used in the present day. The second part is divided into two main sections: the first section is devoted to a study of the English language as it is used in the present day, and the second section is devoted to a study of the English language as it is used in the present day.

APPENDIX A
DETAIL PROCEDURE AND
DESCRIPTION OF EQUIPMENT

DETAILED PROCEDURE

Preliminary Analysis:

The closest approach to a theory for this problem is the work of Lamb⁽⁴⁾ on surface waves due to a moving pressure disturbance.

Though this theory was advanced considering a pressure disturbance at the surface, it was felt that the general method of attack is applicable to disturbances caused by a submerged body. In brief, the theory predicted (a) change of surface elevation over the finite length of the disturbance with the shape of the elevation closely linked to the nature of the disturbance, (b) a transition region of approximately $\frac{1}{2}$ a wave length whose nature was exponential, (c) a damped oscillatory wave. Further, Lord Kelvin had theorized and experimentally checked the fact that no stable wave pattern would result at velocities of less than about 23 cm/sec.⁽⁵⁾

With this background, the method of procedure as stated on page 4 was adopted.

Also apparent in the preliminary analysis was the question of simulating deep water conditions in a channel of this type.

Only this far could theory help; it was necessary to know the general nature of the waves before proceeding.

Sequence of Investigation :

In order to get consistent results, reasonably steady approach flow to the foil had to be achieved. It was considered that this could be accomplished without modification to the channel, as installed, by placing our foil and observation section a distance of about fourteen feet from the inlet. Upon establishing flow with the sluice gate removed from the inlet, it was found that a standing wave existed the entire length of the channel. This difficulty was resolved by lowering the

INITIAL PROCEEDINGS

Preliminary Analysis:

The closest approach to a theory for this problem is the work of Lamb⁽¹⁾ on surface waves due to a moving pressure disturbance. Though this theory was advanced considering a pressure disturbance at the surface, it was felt that the general method of attack is applicable to disturbances caused by a submerged body. In brief, the theory predicts (a) change of surface elevation over the finite length of the disturbance with the shape of the elevation closely linked to the nature of the disturbance, (b) a transition region of approximately $\frac{1}{2}$ a wave length where nature was exponential, (c) a damped oscillatory wave. Further, Lamb's theory had predicted and experimentally checked the fact that the elevation was periodic with respect at velocities of less than about 50 m/sec. (2)

With this background, the method of procedure as stated on page 4

was adopted.

Also apparent in the preliminary analysis was the question of stimulating deep water conditions in a channel of this type. Only this far could theory help; it was necessary to have the general nature of the waves before proceeding.

Sequence of Investigation:

In order to get consistent results, reasonably steady approach flow to the fall had to be achieved. It was considered that this could be accomplished without modification to the channel, as indicated by placing one fall and observation section a distance of about fourteen feet from the inlet. Upon establishing flow with the sluice gate removed from the fall, it was found that a standing wave existed the entire length of the channel. This difficulty was removed by lowering the

sluice gate to create a small head (one to two inches above the level of surface flow) in the inlet tank. This slight contraction of the inlet removed the standing wave, and the length of approach flow was sufficient to take care of the additional surface disturbance caused by the sluice gate.

With satisfactory approach flow established, the foil was placed in the flow; and velocity, submergence and angle of attack were varied to note qualitative effects. Two results were immediately noted: 1) The damping of the wave train was not discernable to the eye; 2) Lord Kelvin's prediction as to minimum velocity was optimistic in terms of stability of this equipment. Only random disturbance was present below a velocity of 1.25 feet per second, and, up to velocities of about 1.4 feet per second, measurement would be difficult.

It was also observed that the foil supports were creating some surface disturbance, and that this disturbance converged at the center of the channel at approximately the second wave crest, independent of the velocity of flow. To the eye, these effects appeared sizable, so it was decided to round the corners of the side supports, and if this did not suffice, to measure the surface profile generated by the supports alone, and try to subtract these values out of the profiles generated by the hydrofoil.

The rounding of the edges of the support pieces produced no change in the size of these disturbances, but, when the supports alone were placed in the flow, there was little or no effect on the surface, and no measurable wave was caused by these supports. Thus, it was decided that the unwanted surface disturbance was being caused, not by the side supports themselves, but by the complex intersection of foil,

The results of the experiment are shown in Table I. The first column gives the velocity of the wave, the second column the distance from the source to the observer, and the third column the time of travel. The values of the velocity are in good agreement with the theoretical value of 330 m/sec. The distance from the source to the observer is 100 m, and the time of travel is 0.30 sec.

wall, and support. This was confirmed by observation that side effect first appeared at the surface at a different horizontal location as depth of the foil was changed (moving downstream, as submergence was increased).

As this could not be eliminated without major changes in the mounting, and it was felt that foil and channel wall alone would produce considerable effect even if the supports were removed from the flow, this three dimensional effect remained throughout the experimentation. However, as plotting of the profiles progressed, it was shown that this effect, though tending to make measurement difficult in the vicinity of the second crest, could be averaged out by careful use of the depth gage. Even with very closely spaced profile points, no appearance of this disturbance could be noted on the plotted profiles at the point where visual observation showed that side effects were present in the centerline profile.

A much more harmful effect of this side effect was its contribution to wave instability, particularly at low velocities, and, if a mounting could be designed to eliminate or reduce these disturbances, a minimum velocity much closer to that predicted by Lord Kelvin might be achieved.

Since this investigation would have been of little value unless it could be related to hydrofoil performance in deep water, it was felt that the first objective must be to determine the effects of the comparatively shallow channel. This was done as follows:

At each of several selected velocities, the controllable variables (angle of attack, depth of submergence, and velocity) were held constant while total depth was varied from the maximum allowed by pump

will, not support. This was confirmed by observation that the
two lines appeared at the surface of a shallow horizontal
as depth of the foil was changed (moving downwards, an adjustment
was necessary).

The foil would not be illuminated without being changed in the
morning, and it was left that day and changed with about two
days' intervals until even if the supports were removed from the
lines, the lines themselves would not be illuminated. The experi-
menter, however, as a matter of the physical properties, it was
found that this effect, which seemed to be a result of the
in the vicinity of the second wall, could be removed out by care-
ful use of the upper plate. Even with very closely spaced profiles
between, an appearance of this appearance could be noted on the high-
ed profiles at the point where the vertical separation across that side
efforts were present in the horizontal profiles.

A main cause which affected the side effect was the distance
from the vertical profiles, particularly at low frequencies, and it is
interesting to be observed in relation to various other observations,
A similar velocity was found to have been affected by the same effect
be observed.

Since this investigation would have been of little value unless
it could be related to specific phenomena in deep water, it was
felt that the first objective was to be to determine the effects of the
comparatively small amount. This was done as follows:
At each of several selected intervals of the experimental procedure
(range of attack, depth of submergence, and wavelength) were held con-
stant while total depth was varied from one extreme to the other by means

capacity to the minimum where total depth was only slightly greater than the depth of submergence. Resulting changes in the characteristics of the generated wave were then the "shallow water effects".

Once the point at which changes occurred was established, investigation proceeded at depths greater than this critical depth and thus deep water runs were simulated.

In addition, the first part of the investigation yielded enough data free of shallow water effects that it was possible to establish the fact that wave length was a function of velocity only.

The remainder of the investigation comprised the collection of sufficient data to establish the effects of α , d_1 , and V on the transition zone and on amplitude of the steady wave.

DESCRIPTION OF EQUIPMENT

THE HYDROFOIL

The hydrofoil selected for this experiment was the N.A.C.A. 4412 airfoil section. The profile of this section is shown in the appendix Table no. I with a tabulation of its coordinates. The choice of this particular profile was based primarily on the availability of existing data of a similar nature which would be useful in the course of this investigation.⁽¹⁾⁽²⁾ This airfoil is 2.8" in chord length and 18" in wing length. It has a 12 percent thickness ratio with a 4 percent camber. The trailing edge was rounded off slightly to facilitate the machining of the foil. The foil was made of dural and was manufactured by a special milling machine in the Sloan Laboratory of the Institute.

THE WATER CHANNEL

A photograph of the water channel is shown in Figure X. This flume is capable of a maximum flow rate of 1200 G.P.M. It is 18" in width and 24 feet in length. The entrance of the channel contained radiator baffling followed by a converging section to stabilize the channel flow rate and produce as little surface disturbance as possible. For the low velocities needed for this investigation (about 1-2 F.P.S.) this arrangement was not quite satisfactory because standing waves were generated on the upstream side of the test section. A satisfactory flow surface was produced by merely lowering the sluice gate until it made contact with the water surface. Surface disturbance variation, (unsteady) was,

at the most, about $1\frac{1}{2}$ millimeters.

The flow rate of the channel was established by means of a calibrated orifice section located in the piping on the discharge side of the pump. A differential mercury manometer was attached to this section and the flow rate could be obtained by measuring the difference in mercury levels. Then applying the calibration formula

$$Q = 1.806 \sqrt{H} \quad (2)$$

the flow rate and hence the velocity could be determined.

THE MEASURING EQUIPMENT

A depth probe, calibrated in centimeters, was used to measure the heights of the generated waves, the undisturbed stream surface and to establish the vertical height of the foil tip. The probe was mounted on a carriage which could be moved on rails located on top of the flume.

A telescope apparatus shown in Fig. XI was used in measuring the horizontal distances. Due to the long arm on the depth probe, inaccurate horizontal distance readings would result if horizontal distances were measured using the probe carriage. The telescope was mounted on a moving slider which was free to move in a horizontal direction along an aluminum $2 \times 2 \times \frac{1}{2}$ " angle. This aluminum angle was securely bolted at each extremity of the observation area and checked for level and cross-level by means of a machinist's level.

A steel tape was laid along the top surface of the angle for use in measuring horizontal distances. Vertical movement of the telescope was achieved by clamping the telescope on a depth probe which in turn was mounted on the slider.

At the point, about 1/2 mile from the shore,

The flow rate of the channel was estimated by means of a calibrated vertical section located in the middle of the channel side of the point. A differential water manometer was attached to this section and the flow rate could be obtained by measuring the difference in water levels. When applying the calibration

formula

$$Q = 1.486 V H^{3/2} \quad (2)$$

the flow rate and hence the velocity could be determined.

THE SURFACE PROFILE

A depth probe, calibrated in centimeters, was used to measure the surface of the channel water, and continuous surface profile was established the vertical distance of the water surface to the bottom of the channel which would be used as a basis for the calculation of the surface profile.

A telescope apparatus was used to measure the horizontal distance. One end of the telescope was mounted on a horizontal distance measuring device which is mounted on a fixed point along the channel. The telescope was mounted on a moving stand which was free to move in a horizontal direction along the channel. This distance was measured by means of a horizontal distance measuring device which was mounted on a fixed point along the channel. The telescope was mounted on a moving stand which was free to move in a horizontal direction along the channel. This distance was measured by means of a horizontal distance measuring device which was mounted on a fixed point along the channel.

A small tape was laid along the top surface of the channel to measure horizontal distance. Vertical movement of the telescope was obtained by clamping the telescope in a depth probe which in turn was mounted on the slider.

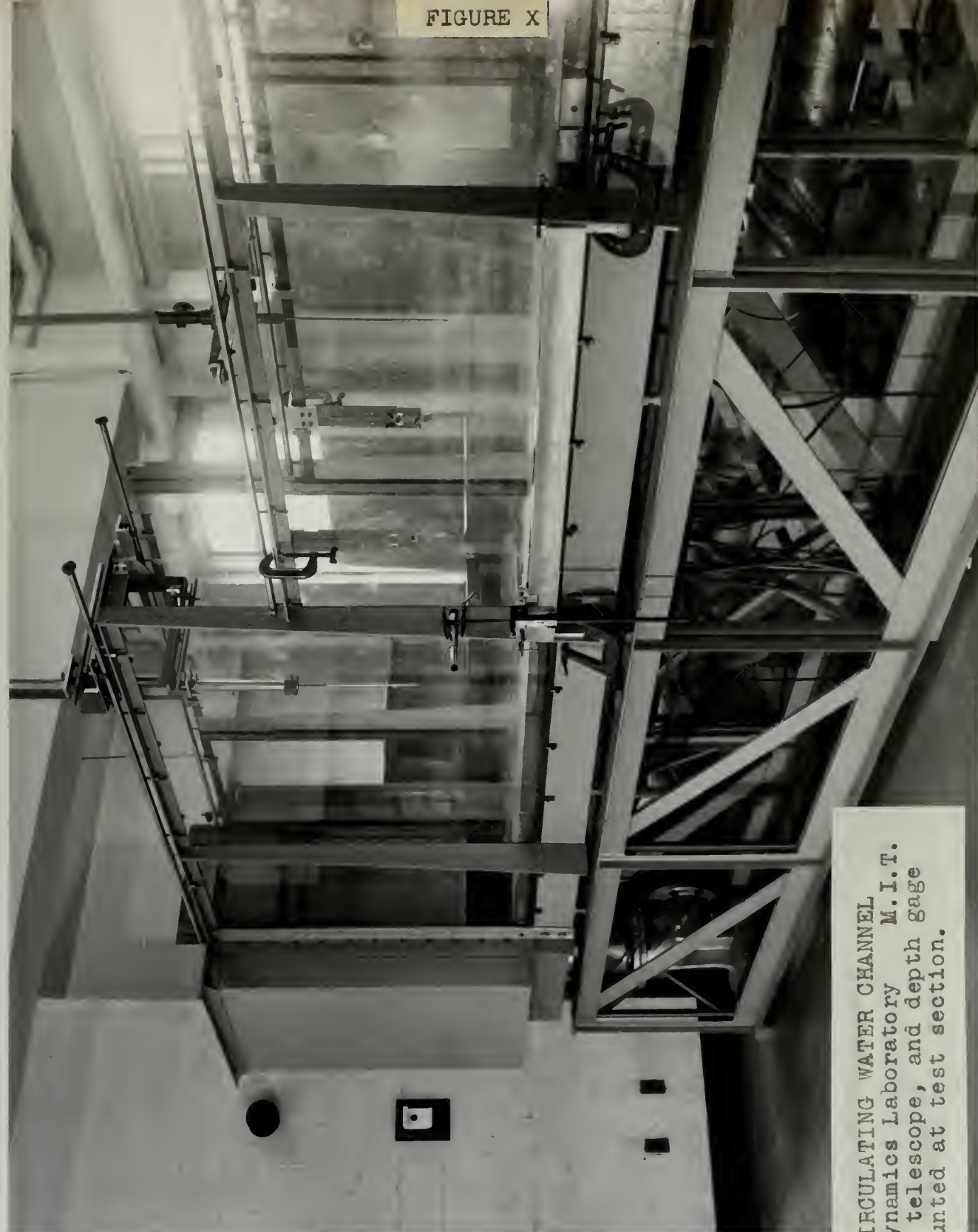
The procedure in using the telescope apparatus is as follows:
the slider is first moved to a desired position on the angle bar.
Then the probe carriage is moved along the length of the flume
until the probe tip is observed in the cross hair of the telescope.
This establishes the abscissa of the particular point on the wave
profile to be measured.

TABLE I
TABLE OF ORDINATES FOR NACA 4412
AIRFOIL SECTION

STATION	UPPER	LOWER	
0	-	0	
1.25	2.44	-1.43	
2.5	3.39	-1.95	
5.0	4.73	-2.49	Leading edge radius = 1.58
7.5	5.76	-2.74	Slope of radius through end of
10.0	6.59	-2.86	chord = $4/20$
15.0	7.89	-2.88	Max. mean camber = $.04 \times C$
20.0	8.80	-2.74	Location of max. mean
25.0	9.41	-2.50	camber = $.4 \times C$
30.0	9.76	-2.26	
40.0	9.80	-1.80	Max. thickness = $.12 \times C$
50.0	9.19	-1.40	
60.0	8.14	-1.00	
70.0	6.69	-0.65	
80.0	4.89	-0.39	
90.0	2.71	-0.22	
95.0	1.47	-0.16	
100.0	0.13	-0.13	
100.0	-	0	

In the above table the stations are expressed as percentages of the chord length. The ordinates to the upper and lower surfaces are also expressed as percentages of chord length.

The foil used in this investigation was designed for a chord length of 2.80 inches. The trailing edge had to be rounded off slightly to facilitate machining. The actual measured chord length was 2.77 inches.



CIRCULATING WATER CHANNEL
Hydrodynamics Laboratory M.I.T.
Foil, telescope, and depth gage
mounted at test section.



TELESCOPE
Close-up showing
mount and bench.



HYDROFOIL
Close-up of foil
and movable mount.

FIGURE XIII



FOIL IN OPERATION

$\alpha = 0.6$ $\lambda = 9.4$ in.
 $V = 2.0$ ft/sec $a = 0.55$ in.
 $d_1 = 3.46$ in.
 $d_0 = 8.27$ in.



FIGURE XIV



FOIL IN OPERATION

$\alpha = 0^\circ$
 $V = 2.5 \text{ ft/sec}$
 $d_1 = 2.08 \text{ in.}$
 $d_0 = 7.68 \text{ in.}$

$\lambda = 14.6 \text{ in.}$
 $a = 0.78 \text{ in.}$

Note surface rise above
hydrofoil.

APPENDIX B
SUMMARY OF DATA AND
CALCULATIONS

THE UNIVERSITY
OF THE STATE OF NEW YORK
ALBANY

TABLE II
SUMMARY OF EXPERIMENTAL DATA

RUN NO.	d ₁ in.	d ₀ in.	α °	V ft/sec	λ in.	a in.	y ₀ in.	y ₁ in.	l ₁ in.	l ₂ in.
7	2.94	9.95	2	1.30	4.5	0.17	0.13	-	2.2	5.0
8	2.92	10.24	2	1.83	8.0	0.50	0.37	-	3.9	R
9	2.94	6.72	2	1.40	5.7	0.42	0.23	-	2.6	5.6
10	2.93	9.03	2	1.72	7.3	0.61	0.30	-	3.8	7.6
11	2.97	7.77	2	1.60	6.1	0.44	0.24	-	2.9	6.6
12	2.94	8.70	2	1.19	4.1	0.13	0.16	-	2.2	4.6
13	2.94	7.20	2	1.98	8.4	0.72	0.43	-	4.2	R
14	2.90	4.75	2	1.32	5.5	0.34	0.16	-	2.3	5.7
15	2.99	6.44	2	1.29	4.8	0.29	0.18	-	2.3	5.5
16	2.93	7.70	2	1.31	5.0	0.24	0.16	-	2.7	5.4
17	2.93	6.72	2	2.51	16.0	1.30	0.64	-	6.5	14.2
18	2.91	4.44	2	2.51	19.3	1.46	0.77	-	7.6	17.0
19	2.97	5.57	2	2.48	16.0	1.40	0.66	-	6.0	14.7
20	2.54	6.95	2	2.24	12.0	1.10	0.45	-	5.2	R
21	3.01	6.32	2	2.03	9.2	0.61	0.43	-	4.0	R
22	3.02	8.4	2	1.99	9.2	0.62	0.47	-	3.9	R
23	2.94	9.2	2	1.97	8.6	0.58	0.37	-	4.2	R
24	2.93	4.66	2	2.01	11.0	0.37	0.52	-	5.2	R
25	2.03	3.53	2	2.00	12.2	0.85	0.63	-	5.3	R
26	2.00	7.5	2	1.84	8.3	0.48	0.41	-	4.4	R
27.5	2.00	7.5	2	2.06	10.1	0.85	0.47	-	5.0	R
28	2.00	7.5	2	2.30	12.0	1.02	0.47	-	6.0	R
29a	1.00	8.31	0	2.00	9.2	0.70	0.26	0.28	4.6	9.5
29b	1.76	8.31	0	2.00	9.4	0.76	0.27	0.16	4.6	9.5
29c	2.50	8.31	0	2.00	9.4	0.73	0.30	-	4.6	9.5
30a	3.51	8.31	0	2.00	10.0	0.57	0.21	-	4.6	9.5
30b	4.50	8.31	0	2.00	10.0	0.40	0.17	-	4.6	9.5
31a	4.88	8.31	2	2.00		0.42	0.22	-	4.2	9.7
31b	4.13	8.31	2	2.00		0.60	0.32	-	4.2	9.7
31c	3.44	8.31	2	2.00		0.78	0.38	-	4.2	9.7
36a	3.85	8.31	3	2.00		0.79	0.45	-	4.2	9.6
36b	4.98	8.31	3	2.00		0.42	0.28	-	4.2	9.6
36c	4.36	8.31	3	2.00		0.57	0.34	-	4.2	9.6
37a	2.64	8.31	1	2.00		0.81	0.43	-	4.2	9.7
37b	3.15	8.31	1	2.00		0.75	0.45	-	4.2	9.7
37c	3.86	8.31	1	2.00		0.62	0.36	-	4.2	9.7
37d	4.70	8.31	1	2.00		0.43	0.21	-	4.2	9.7
38a	4.96	8.31	-1	2.00		0.26	0.16	-	4.4	9.7
38b	4.05	8.31	-1	2.00		0.41	0.20	-	4.4	9.7
38c	3.15	8.31	-1	2.00		0.58	0.28	-	4.4	9.7
38d	2.25	8.31	-1	2.00		0.67	0.32	0.06	4.4	9.7
39	1.16	8.31	-1	2.00		0.64	0.26	0.22	4.4	9.7
40a	4.75	7.65	3	2.51		0.91	0.43	-	6.3	15.4
40b	3.77	7.65	3	2.51		1.20	0.55	-	6.3	15.4

TABLE II
(cont'd)

RUN NO.	d_1 in.	d_0 in.	α o	V ft/sec	λ in.	a in.	y_0 in.	y_1 in.	l_1 in.	l_2 in.
40c	2.76	7.65	3	2.51		1.34	0.63	-	6.3	15.4
40d	1.80	7.65	3	2.51		1.24	0.71	0.03	6.3	15.4
41a	0.82	7.65	3	2.51		0.92	0.49	0.24	6.3	15.4
41b	4.78	7.65	2	2.51		0.80	0.45	-	6.3	15.2
41c	3.77	7.65	2	2.51		1.09	0.52	-	6.3	15.2
41d	2.80	7.65	2	2.51		1.26	0.63	-	6.3	15.2
41e	1.80	7.65	2	2.51		1.18	0.57	0.08	6.3	15.2
41f	0.81	7.65	2	2.51		0.77	0.43	0.19	6.3	15.2
41g	4.80	7.65	1	2.51		0.70	0.39	-	6.4	15.3
41h	3.81	7.65	1	2.51		0.91	0.45	-	6.4	15.3
42a	2.84	7.65	1	2.51		1.05	0.49	0.04	6.4	15.3
42b	1.82	7.65	1	2.51		1.05	0.52	0.12	6.4	15.3
42c	0.84	7.65	1	2.51		0.74	0.38	0.20	6.4	15.3
42d	4.85	7.65	0			0.50	0.33	-	6.3	15.2
42e	3.85	7.65	0	2.51		0.65	0.37	-	6.3	15.2
42f	2.85	7.65	0	2.51		0.74	0.43	0.06	6.3	15.2
42g	1.85	7.65	0	2.51		0.78	0.45	0.10	6.3	15.2
42h	0.86	7.65	0	2.51		0.63	0.28	0.18	6.3	15.2
43a	4.85	7.65	-1	2.51		0.41	0.30	-	6.4	15.6
43b	3.86	7.65	-1	2.51		0.54	0.35	-	6.4	15.6
43c	2.84	7.65	-1	2.51		0.67	0.37	0.04	6.4	15.6
43d	1.85	7.65	-1	2.51		0.71	0.37	0.14	6.4	15.6
43e	0.87	7.65	-1	2.51		0.52	0.26	0.24	6.4	15.6
44a	2.98	9.65	3	1.50						
44b	3.72	9.65	3	1.50						
44c	4.50	9.65	3	1.50						
44d	3.42	9.65	3	1.50						
44e	3.01	9.65	2	1.50						
44f	3.51	9.65	2	1.50						
44g	4.04	9.65	2	1.50						
44h	3.02	9.65	1	1.50						
44i	3.54	9.65	1	1.50						
44j	4.05	9.65	1	1.50						
44k	2.57	9.65	0	1.50						
44l	3.04	9.65	0	1.50						
44m	3.54	9.65	0	1.50						
44n	2.55	9.65	-1	1.50						
44o	3.04	9.65	-1	1.50						
44p	3.58	9.65	-1	1.50						

This data not taken
in following runs

NOTE: 1) R in l_2 column indicates breaking at first wave crest.
2) - in y_1 column indicates no surface rise directly above foil.

[illegible]

TABLE II
(cont'd)

Limits of accuracy in terms of probable error.

d_1	0.02	in.
d_0	0.02	in.
α	0.1°	
v	0.01	ft/sec.
λ	0.3	in.
a	0.05	in.
y_0	0.02	in.
y_1	0.02	in.
l_1	0.2	in.
l_2	0.4	in.

λ	λ/λ_0	λ/λ_0	λ/λ_0	λ/λ_0	λ/λ_0
1.0	1.000	1.000	1.000	1.000	1.000
1.1	0.909	1.100	0.909	1.100	0.909
1.2	0.833	1.200	0.833	1.200	0.833
1.3	0.769	1.300	0.769	1.300	0.769
1.4	0.714	1.400	0.714	1.400	0.714
1.5	0.667	1.500	0.667	1.500	0.667
1.6	0.625	1.600	0.625	1.600	0.625
1.7	0.588	1.700	0.588	1.700	0.588
1.8	0.556	1.800	0.556	1.800	0.556
1.9	0.526	1.900	0.526	1.900	0.526
2.0	0.500	2.000	0.500	2.000	0.500

Limitations of λ_1 , λ_2 , and λ_3 are shown in terms of λ in the above table. The limits of accuracy in terms of the standard deviation of the measured quantities are shown in the same table. The limits of accuracy in terms of the standard deviation of the measured quantities are shown in the same table.

$$\frac{\lambda}{\lambda_0} = \left(\frac{\lambda}{\lambda_0} \right)^2$$

where λ_0 is the wavelength of the light.

Amount of meat in pounds in various grades

1st	30.0
2nd	20.0
3rd	10.0
4th	10.0
5th	10.0
6th	10.0
7th	10.0
8th	10.0
9th	10.0
10th	10.0

TABLE III

TABULATION OF DATA FOR THE PLOT OF THE VARIATION
OF WAVE-LENGTH WITH DEPTH OF WATER TO
NOTE SHALLOW-WATER EFFECTS

V = 1.30 ft./sec.		$\alpha = 2^\circ$		$d_1 = 2.940$ in.	
Run	do(ft.)	V ft./sec.	V^2	λ ft.	λ (corrected)
7	0.829	1.300	1.69	0.375	0.375
9	0.560	1.485	2.21	0.475	0.363
10	0.752	1.720	2.96	0.608	0.347
11	0.647	1.595	2.55	0.508	0.337
14	0.396	1.320	1.75	0.458	0.413
15	0.536	1.294	1.68	0.396	0.398
16	0.641	1.310	1.72	0.416	0.408

V = 2.00 ft./sec.		$\alpha = 2^\circ$		$d_1 = 2.940$ in.	
Run	do	V	V^2	λ	λ (corrected)
13	0.600	1.975	3.90	0.700	0.718
20	0.579	2.240	5.02	1.000	0.798
21	0.526	2.030	4.13	0.766	0.742
22	0.700	1.990	3.96	0.766	0.774
23	0.718	1.972	3.89	0.716	0.736
24	0.388	2.010	4.04	0.917	0.908
25	0.294	2.000	4.00	1.017	1.017
30	0.689	1.980	3.93	0.750	0.764

V = 2.5 ft./sec.		$\alpha = 2^\circ$		$d_1 = 2.94$ in.	
Run	do	V	V^2	λ	λ (corrected)
17	0.559	2.510	6.32	1.333	1.319
18	0.370	2.510	6.32	1.608	1.59
19	0.464	2.480	6.15	1.333	1.356
40	0.636	2.510	6.32	1.250	1.245

Velocities of 1.3, 2.0, and 2.5 ft./sec. were chosen to show on the curve because most of the runs made during the early part of the investigation were at velocities near these. As shown above all of the wave-lengths were corrected by proportioning based on the ratio of the square of the velocities

$$\frac{\lambda_1}{\lambda_2} = \left(\frac{V_1}{V_2} \right)^2 \quad (3)$$

which was previously established.

MONITORING AND CONTROL OF THE VARIATION
OF WATER QUALITY WITH RESPECT TO
THE QUALITY OF THE WATER

Time		Lat		Long		Alt		Dist	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

λ	μ	ν	ρ	σ	τ
0.000	0.000	0.000	0.000	0.000	0.000
0.001	0.001	0.001	0.001	0.001	0.001
0.002	0.002	0.002	0.002	0.002	0.002
0.003	0.003	0.003	0.003	0.003	0.003
0.004	0.004	0.004	0.004	0.004	0.004
0.005	0.005	0.005	0.005	0.005	0.005
0.006	0.006	0.006	0.006	0.006	0.006
0.007	0.007	0.007	0.007	0.007	0.007
0.008	0.008	0.008	0.008	0.008	0.008
0.009	0.009	0.009	0.009	0.009	0.009
0.010	0.010	0.010	0.010	0.010	0.010

λ	μ	ν	ξ	η	θ
0.000	0.000	0.000	0.000	0.000	0.000
0.001	0.001	0.001	0.001	0.001	0.001
0.002	0.002	0.002	0.002	0.002	0.002
0.003	0.003	0.003	0.003	0.003	0.003
0.004	0.004	0.004	0.004	0.004	0.004
0.005	0.005	0.005	0.005	0.005	0.005
0.006	0.006	0.006	0.006	0.006	0.006
0.007	0.007	0.007	0.007	0.007	0.007
0.008	0.008	0.008	0.008	0.008	0.008
0.009	0.009	0.009	0.009	0.009	0.009

[illegible]

$$\left(\frac{10}{57}\right) = \frac{10}{57}$$

which are positively correlated.

TABLE IV

TABULATION OF DATA FOR THE PLOT OF VELOCITY VS
WAVE-LENGTH FOR SHIP WATER OPERATIONS

Run	V	λ	λ'
8	1.83	8.00	.666
10	1.72	7.30	.608
11	1.595	6.10	.508
17	2.51	16.00	1.334
20	2.24	12.00	1.00
22	1.99	9.20	.766
23	1.97	8.60	.716
26	1.835	8.30	.692
26.5	2.45	14.0	1.166
29-30	1.98	9.6	.800
40	2.48	15.00	1.25

The following calculations serve to substantiate the theory. From the curve of velocity versus wave-length the following points were taken:

$$\begin{aligned}\lambda &= 1.76 \text{ ft.} & V &= 3.00 \text{ ft./sec.} \\ \lambda &= 0.44 \text{ ft.} & V &= 1.50 \text{ ft./sec.}\end{aligned}$$

The equation is of the form:

$$\lambda = KV^n \quad (4)$$

$$(1.76 = K(3.00)^n$$

$$(0.44 = K(1.50)^n$$

$$\ln \lambda = \ln K + n(\ln V)$$

$$\ln 1.76 = \ln K + n \ln 3.00$$

$$\ln 0.44 = \ln K + n \ln 1.50$$

$$0.565 = \ln K + n 1.098$$

$$-0.823 = \ln K + n 0.405$$

$$1.388 = 0.693 n$$

$$\therefore n = 2$$

$$0.565 = \ln K + 2 (1.098)$$

$$\ln K = -1.631$$

$$K = 0.195$$

$$\therefore \lambda = 0.195 V^2 = \frac{2\pi}{g} V^2$$

VI

TABLE IV
RELATIONSHIP BETWEEN THE RATE OF GROWTH OF THE
POPULATION AND THE RATE OF GROWTH OF THE
ECONOMY

Year	Rate of Growth of the Economy (%)	Rate of Growth of the Population (%)
1950	1.50	1.50
1951	1.50	1.50
1952	1.50	1.50
1953	1.50	1.50
1954	1.50	1.50
1955	1.50	1.50
1956	1.50	1.50
1957	1.50	1.50
1958	1.50	1.50
1959	1.50	1.50
1960	1.50	1.50
1961	1.50	1.50
1962	1.50	1.50
1963	1.50	1.50
1964	1.50	1.50
1965	1.50	1.50
1966	1.50	1.50
1967	1.50	1.50
1968	1.50	1.50
1969	1.50	1.50
1970	1.50	1.50
1971	1.50	1.50
1972	1.50	1.50
1973	1.50	1.50
1974	1.50	1.50
1975	1.50	1.50
1976	1.50	1.50
1977	1.50	1.50
1978	1.50	1.50
1979	1.50	1.50
1980	1.50	1.50
1981	1.50	1.50
1982	1.50	1.50
1983	1.50	1.50
1984	1.50	1.50
1985	1.50	1.50
1986	1.50	1.50
1987	1.50	1.50
1988	1.50	1.50
1989	1.50	1.50
1990	1.50	1.50
1991	1.50	1.50
1992	1.50	1.50
1993	1.50	1.50
1994	1.50	1.50
1995	1.50	1.50
1996	1.50	1.50
1997	1.50	1.50
1998	1.50	1.50
1999	1.50	1.50
2000	1.50	1.50
2001	1.50	1.50
2002	1.50	1.50
2003	1.50	1.50
2004	1.50	1.50
2005	1.50	1.50
2006	1.50	1.50
2007	1.50	1.50
2008	1.50	1.50
2009	1.50	1.50
2010	1.50	1.50
2011	1.50	1.50
2012	1.50	1.50
2013	1.50	1.50
2014	1.50	1.50
2015	1.50	1.50
2016	1.50	1.50
2017	1.50	1.50
2018	1.50	1.50
2019	1.50	1.50
2020	1.50	1.50
2021	1.50	1.50
2022	1.50	1.50
2023	1.50	1.50
2024	1.50	1.50
2025	1.50	1.50
2026	1.50	1.50
2027	1.50	1.50
2028	1.50	1.50
2029	1.50	1.50
2030	1.50	1.50
2031	1.50	1.50
2032	1.50	1.50
2033	1.50	1.50
2034	1.50	1.50
2035	1.50	1.50
2036	1.50	1.50
2037	1.50	1.50
2038	1.50	1.50
2039	1.50	1.50
2040	1.50	1.50
2041	1.50	1.50
2042	1.50	1.50
2043	1.50	1.50
2044	1.50	1.50
2045	1.50	1.50
2046	1.50	1.50
2047	1.50	1.50
2048	1.50	1.50
2049	1.50	1.50
2050	1.50	1.50
2051	1.50	1.50
2052	1.50	1.50
2053	1.50	1.50
2054	1.50	1.50
2055	1.50	1.50
2056	1.50	1.50
2057	1.50	1.50
2058	1.50	1.50
2059	1.50	1.50
2060	1.50	1.50
2061	1.50	1.50
2062	1.50	1.50
2063	1.50	1.50
2064	1.50	1.50
2065	1.50	1.50
2066	1.50	1.50
2067	1.50	1.50
2068	1.50	1.50
2069	1.50	1.50
2070	1.50	1.50
2071	1.50	1.50
2072	1.50	1.50
2073	1.50	1.50
2074	1.50	1.50
2075	1.50	1.50
2076	1.50	1.50
2077	1.50	1.50
2078	1.50	1.50
2079	1.50	1.50
2080	1.50	1.50
2081	1.50	1.50
2082	1.50	1.50
2083	1.50	1.50
2084	1.50	1.50
2085	1.50	1.50
2086	1.50	1.50
2087	1.50	1.50
2088	1.50	1.50
2089	1.50	1.50
2090	1.50	1.50
2091	1.50	1.50
2092	1.50	1.50
2093	1.50	1.50
2094	1.50	1.50
2095	1.50	1.50
2096	1.50	1.50
2097	1.50	1.50
2098	1.50	1.50
2099	1.50	1.50
2100	1.50	1.50

The following table shows the relationship between the rate of growth of the economy and the rate of growth of the population. The rate of growth of the economy is shown in the first column and the rate of growth of the population is shown in the second column.

$$\begin{aligned} \lambda &= 1.50 \text{ per cent} \\ \lambda &= 1.50 \text{ per cent} \end{aligned}$$

The equation is of the form

$$\lambda = 1.50$$

(1)

$$\begin{aligned} (1.50 \times 100) &= 150 \\ (1.50 \times 100) &= 150 \\ (1.50 \times 100) &= 150 \end{aligned}$$

$$\begin{aligned} 150 \times 100 &= 15000 \\ 150 \times 100 &= 15000 \end{aligned}$$

$$\begin{aligned} 150 \times 100 &= 15000 \\ 150 \times 100 &= 15000 \end{aligned}$$

$$\begin{aligned} 150 \times 100 &= 15000 \\ 150 \times 100 &= 15000 \end{aligned}$$

$$\lambda = 1.50 \text{ per cent}$$

$\alpha = 0$ $\alpha = 0$ $\alpha = 0$ $\alpha = 0$

د/ب	د/ب	د/ب	د/ب	د/ب	د/ب	د/ب	د/ب	د/ب	د/ب
۱۵۰.۰	۲۲۰.۰	۳۰۰.۰	۳۸۰.۰	۴۵۰.۰	۵۲۰.۰	۶۰۰.۰	۶۸۰.۰	۷۵۰.۰	۸۰۰.۰
۱۶۰.۰	۲۳۰.۰	۳۱۰.۰	۳۹۰.۰	۴۶۰.۰	۵۳۰.۰	۶۱۰.۰	۶۹۰.۰	۷۶۰.۰	۸۱۰.۰
۱۷۰.۰	۲۴۰.۰	۳۲۰.۰	۴۰۰.۰	۴۷۰.۰	۵۴۰.۰	۶۲۰.۰	۷۰۰.۰	۷۷۰.۰	۸۲۰.۰
۱۸۰.۰	۲۵۰.۰	۳۳۰.۰	۴۱۰.۰	۴۸۰.۰	۵۵۰.۰	۶۳۰.۰	۷۱۰.۰	۷۸۰.۰	۸۳۰.۰
۱۹۰.۰	۲۶۰.۰	۳۴۰.۰	۴۲۰.۰	۴۹۰.۰	۵۶۰.۰	۶۴۰.۰	۷۲۰.۰	۷۹۰.۰	۸۴۰.۰
۲۰۰.۰	۲۷۰.۰	۳۵۰.۰	۴۳۰.۰	۵۰۰.۰	۵۷۰.۰	۶۵۰.۰	۷۳۰.۰	۸۰۰.۰	۸۵۰.۰
۲۱۰.۰	۲۸۰.۰	۳۶۰.۰	۴۴۰.۰	۵۱۰.۰	۵۸۰.۰	۶۶۰.۰	۷۴۰.۰	۸۱۰.۰	۸۶۰.۰

$$V = 5.00 \text{ m/s} \quad F = 0.333 \quad \alpha = 0.5$$
[illegible]
$$V = 1.70 \text{ km}^3/\text{year}$$
$$\dot{E}_T = 6.220$$
$$\alpha = -10$$
$$\alpha = -90$$
$$\alpha = -80$$
$$\alpha = -70$$

2/0	2/2	2/4	2/6	2/8	2/10	2/12	2/14	2/16	2/18
200.1	210.0	220.1	230.0	240.1	250.0	260.1	270.0	280.1	290.0
290.1	300.0	310.1	320.0	330.1	340.0	350.1	360.0	370.1	380.0
390.1	400.0	410.1	420.0	430.1	440.0	450.1	460.0	470.1	480.0
490.1	500.0	510.1	520.0	530.1	540.0	550.1	560.0	570.1	580.0
590.1	600.0	610.1	620.0	630.1	640.0	650.1	660.0	670.1	680.0
690.1	700.0	710.1	720.0	730.1	740.0	750.1	760.0	770.1	780.0
790.1	800.0	810.1	820.0	830.1	840.0	850.1	860.0	870.1	880.0
890.1	900.0	910.1	920.0	930.1	940.0	950.1	960.0	970.1	980.0
990.1	1000.0	1010.1	1020.0	1030.1	1040.0	1050.1	1060.0	1070.1	1080.0
1090.1	1100.0	1110.1	1120.0	1130.1	1140.0	1150.1	1160.0	1170.1	1180.0
1190.1	1200.0	1210.1	1220.0	1230.1	1240.0	1250.1	1260.0	1270.1	1280.0
1290.1	1300.0	1310.1	1320.0	1330.1	1340.0	1350.1	1360.0	1370.1	1380.0
1390.1	1400.0	1410.1	1420.0	1430.1	1440.0	1450.1	1460.0	1470.1	1480.0
1490.1	1500.0	1510.1	1520.0	1530.1	1540.0	1550.1	1560.0	1570.1	1580.0
1590.1	1600.0	1610.1	1620.0	1630.1	1640.0	1650.1	1660.0	1670.1	1680.0
1690.1	1700.0	1710.1	1720.0	1730.1	1740.0	1750.1	1760.0	1770.1	1780.0
1790.1	1800.0	1810.1	1820.0	1830.1	1840.0	1850.1	1860.0	1870.1	1880.0
1890.1	1900.0	1910.1	1920.0	1930.1	1940.0	1950.1	1960.0	1970.1	1980.0
1990.1	2000.0	2010.1	2020.0	2030.1	2040.0	2050.1	2060.0	2070.1	2080.0
2090.1	2100.0	2110.1	2120.0	2130.1	2140.0	2150.1	2160.0	2170.1	2180.0
2190.1	2200.0	2210.1	2220.0	2230.1	2240.0	2250.1	2260.0	2270.1	2280.0
2290.1	2300.0	2310.1	2320.0	2330.1	2340.0	2350.1	2360.0	2370.1	2380.0
2390.1	2400.0	2410.1	2420.0	2430.1	2440.0	2450.1	2460.0	2470.1	2480.0
2490.1	2500.0	2510.1	2520.0	2530.1	2540.0	2550.1	2560.0	2570.1	2580.0
2590.1	2600.0	2610.1	2620.0	2630.1	2640.0	2650.1	2660.0	2670.1	2680.0
2690.1	2700.0	2710.1	2720.0	2730.1	2740.0	2750.1	2760.0	2770.1	2780.0
2790.1	2800.0	2810.1	2820.0	2830.1	2840.0	2850.1	2860.0	2870.1	2880.0
2890.1	2900.0	2910.1	2920.0	2930.1	2940.0	2950.1	2960.0	2970.1	2980.0
2990.1	3000.0	3010.1	3020.0	3030.1	3040.0	3050.1	3060.0	3070.1	3080.0
3090.1	3100.0	3110.1	3120.0	3130.1	3140.0	3150.1	3160.0	3170.1	3180.0
3190.1	3200.0	3210.1	3220.0	3230.1	3240.0	3250.1	3260.0	3270.1	3280.0
3290.1	3300.0	3310.1	3320.0	3330.1	3340.0	3350.1	3360.0	3370.1	3380.0

TABLE VI
NUMERICAL AVERAGES RELATING THE
TRANSITION TO THE STEADY WAVE

Run	$y_0/a(\%)$	Run	$L_1/\lambda(\%)$	Run	$\frac{L_2}{\lambda}$
31a	52	7	49	7	1.11
b	54	8	49	9	0.98
c	50	9	46	10	1.04
36a	57	10	52	11	1.08
b	67	11	48	12	1.11
c	59	12	54	13	1.04
37a	53	13	49	15	1.14
b	60	15	48	16	1.08
c.	58	16	54	29a	1.03
d	49	23	49	29b	1.01
38a	62	26	53	29c	1.01
b	49	27.5	50	30a	0.95
c	48	28	50	30b	0.95
d	48				
39	44				
40a	47	Avg.	50	Avg.	1.04
b	46	Min.	46	Min.	0.95
c	47	Max.	54	Max.	1.14
d	57				
41a	53				
b	56				
c	48				
d	51				
e	48				
f	56				
g	56				
h	50				
42a	47				
b	50				
c	51				
d	66				
e	57				
f	58				
g	58				
h	44				
43b	65				
c	55				
d	52				
e	50				
Avg.	53.3				
Min.	44				
Max.	67				

TABLE VI

OVERALL AVERAGE RESULTS FOR
TRANSITION TO THE STEADY STATE

$\frac{d^2}{\lambda}$	mm	λ (Å)	mm	λ (Å)	mm
11.1	7	92	1	21	121
12.0	8	91	2	22	122
13.1	10	90	3	23	123
14.0	11	89	4	24	124
15.1	12	88	5	25	125
16.0	13	87	6	26	126
17.1	14	86	7	27	127
18.0	15	85	8	28	128
19.1	16	84	9	29	129
20.0	17	83	10	30	130
21.1	18	82	11	31	131
22.0	19	81	12	32	132
23.1	20	80	13	33	133
24.0	21	79	14	34	134
25.1	22	78	15	35	135
26.0	23	77	16	36	136
27.1	24	76	17	37	137
28.0	25	75	18	38	138
29.1	26	74	19	39	139
30.0	27	73	20	40	140
31.1	28	72	21	41	141
32.0	29	71	22	42	142
33.1	30	70	23	43	143
34.0	31	69	24	44	144
35.1	32	68	25	45	145
36.0	33	67	26	46	146
37.1	34	66	27	47	147
38.0	35	65	28	48	148
39.1	36	64	29	49	149
40.0	37	63	30	50	150
41.1	38	62	31	51	151
42.0	39	61	32	52	152
43.1	40	60	33	53	153
44.0	41	59	34	54	154
45.1	42	58	35	55	155
46.0	43	57	36	56	156
47.1	44	56	37	57	157
48.0	45	55	38	58	158
49.1	46	54	39	59	159
50.0	47	53	40	60	160
51.1	48	52	41	61	161
52.0	49	51	42	62	162
53.1	50	50	43	63	163
54.0	51	49	44	64	164
55.1	52	48	45	65	165
56.0	53	47	46	66	166
57.1	54	46	47	67	167
58.0	55	45	48	68	168
59.1	56	44	49	69	169
60.0	57	43	50	70	170
61.1	58	42	51	71	171
62.0	59	41	52	72	172
63.1	60	40	53	73	173
64.0	61	39	54	74	174
65.1	62	38	55	75	175
66.0	63	37	56	76	176
67.1	64	36	57	77	177
68.0	65	35	58	78	178
69.1	66	34	59	79	179
70.0	67	33	60	80	180
71.1	68	32	61	81	181
72.0	69	31	62	82	182
73.1	70	30	63	83	183
74.0	71	29	64	84	184
75.1	72	28	65	85	185
76.0	73	27	66	86	186
77.1	74	26	67	87	187
78.0	75	25	68	88	188
79.1	76	24	69	89	189
80.0	77	23	70	90	190
81.1	78	22	71	91	191
82.0	79	21	72	92	192
83.1	80	20	73	93	193
84.0	81	19	74	94	194
85.1	82	18	75	95	195
86.0	83	17	76	96	196
87.1	84	16	77	97	197
88.0	85	15	78	98	198
89.1	86	14	79	99	199
90.0	87	13	80	100	200
91.1	88	12	81	101	201
92.0	89	11	82	102	202
93.1	90	10	83	103	203
94.0	91	9	84	104	204
95.1	92	8	85	105	205
96.0	93	7	86	106	206
97.1	94	6	87	107	207
98.0	95	5	88	108	208
99.1	96	4	89	109	209
100.0	97	3	90	110	210
101.1	98	2	91	111	211
102.0	99	1	92	112	212
103.1	100	0	93	113	213
104.0	101	0	94	114	214
105.1	102	0	95	115	215
106.0	103	0	96	116	216
107.1	104	0	97	117	217
108.0	105	0	98	118	218
109.1	106	0	99	119	219
110.0	107	0	100	120	220
111.1	108	0	101	121	221
112.0	109	0	102	122	222
113.1	110	0	103	123	223
114.0	111	0	104	124	224
115.1	112	0	105	125	225
116.0	113	0	106	126	226
117.1	114	0	107	127	227
118.0	115	0	108	128	228
119.1	116	0	109	129	229
120.0	117	0	110	130	230
121.1	118	0	111	131	231
122.0	119	0	112	132	232
123.1	120	0	113	133	233
124.0	121	0	114	134	234
125.1	122	0	115	135	235
126.0	123	0	116	136	236
127.1	124	0	117	137	237
128.0	125	0	118	138	238
129.1	126	0	119	139	239
130.0	127	0	120	140	240
131.1	128	0	121	141	241
132.0	129	0	122	142	242
133.1	130	0	123	143	243
134.0	131	0	124	144	244
135.1	132	0	125	145	245
136.0	133	0	126	146	246
137.1	134	0	127	147	247
138.0	135	0	128	148	248
139.1	136	0	129	149	249
140.0	137	0	130	150	250
141.1	138	0	131	151	251
142.0	139	0	132	152	252
143.1	140	0	133	153	253
144.0	141	0	134	154	254
145.1	142	0	135	155	255
146.0	143	0	136	156	256
147.1	144	0	137	157	257
148.0	145	0	138	158	258
149.1	146	0	139	159	259
150.0	147	0	140	160	260
151.1	148	0	141	161	261
152.0	149	0	142	162	262
153.1	150	0	143	163	263
154.0	151	0	144	164	264
155.1	152	0	145	165	265
156.0	153	0	146	166	266
157.1	154	0	147	167	267
158.0	155	0	148	168	268
159.1	156	0	149	169	269
160.0	157	0	150	170	270
161.1	158	0	151	171	271
162.0	159	0	152	172	272
163.1	160	0	153	173	273
164.0	161	0	154	174	274
165.1	162	0	155	175	275
166.0	163	0	156	176	276
167.1	164	0	157	177	277
168.0	165	0	158	178	278
169.1	166	0	159	179	279
170.0	167	0	160	180	280
171.1	168	0	161	181	281
172.0	169	0	162	182	282
173.1	170	0	163	183	283
174.0	171	0	164	184	284
175.1	172	0	165	185	285
176.0	173	0	166	186	286
177.1	174	0	167	187	287
178.0	175	0	168	188	288
179.1	176	0	169	189	289
180.0	177	0	170	190	290
181.1	178	0	171	191	291
182.0	179	0	172	192	292
183.1	180	0	173	193	293
184.0	181	0	174	194	294
185.1	182	0	175	195	295
186.0	183	0	176	196	296
187.1	184	0	177	197	297
188.0	185	0	178	198	298
189.1	186	0	179	199	299
190.0	187	0	180	200	300
191.1	188	0	181	201	301
192.0	189	0	182	202	302
193.1	190	0	183	203	303
194.0	191	0	184	204	304
195.1	192	0	185	205	305
196.0	193	0	186	206	306
197.1	194	0	187	207	307
198.0	195	0	188	208	308
199.1	196	0	189	209	309
200.0	197	0	190	210	310
201.1	198	0	191	211	311
202.0	199	0	192	212	312
203.1	200	0	193	213	313
204.0	201	0	194	214	314
205.1	202	0	195	215	315
206.0	203	0	196	216	316
207.1	204	0	197	217	317
208.0	205	0	198	218	318
209.1	206	0	199	219	319
210.0	207	0	200	220	320
211.1	208	0	201	221	321
212.0	209	0	202	222	322
213.1	210	0	203	223	323
214.0	211	0	204	224	324
215.1	212	0	205	225	325
216.0	213	0	206	226	326
217.1	214	0	207	227	327
218.0	215	0	208	228	328
219.1	216	0	209	229	329
220.0	217	0	210	230	330
221.1	218	0	211	231	331
222.0	219	0	212	232	332
223.1	220	0	213	233	333
224.0	221	0	214	234	334
225.1	222	0	215	235	335
226.0	223	0	216	236	336
227.1	224	0	217	237	337
228.0	225	0	218	238	338
229.1	226	0	219	239	339
230.0	227	0	220	240	340
231.1	228	0	221	241	341
232.0	229	0	222	242	342
233.1	230	0	223	243	343
234.0	231	0	224	244	344
235.1	232	0	225	245	345
236.0	233	0	226	246	346
237.1	234	0	227	247	347
238.0	235	0	228	248	348
239.1	236	0	229	249	349
240.0	237	0	230	250	350
241.1	238	0	231	251	351
242.0	239	0	232	252	352
243.1	240	0	233	253	353
244.0	241	0	234	254	354
245.1	242	0	235	255	355
246.0	243	0			

TABLE VII

SAMPLE DATA SHEET (RUN 29a)

Manometer 1.30 feet, $\alpha \approx 0^\circ$

Foil Location: vertical 35.25 cm., horizontal 16.70 cm.

PROFILE DATA

VERTICAL	HORIZONTAL	VERTICAL	HORIZONTAL
36.75	11.00	35.80	31.00
36.76	13.00	35.97	32.00
36.79	14.00	36.56	33.00
36.92	15.00	37.41	34.00
36.98	16.00	37.75	35.00
37.42	17.00	37.19	36.50
37.47	17.40	36.11	38.00
37.61	18.20	35.86	39.50
37.01	19.00	36.08	41.00
36.57	20.00	36.87	42.50
36.25	21.00	37.36	44.00
36.10	22.00		
36.31	23.00		
36.69	24.00		
37.25	25.00		
37.75	26.00		
37.55	27.00		
37.09	28.00		
36.50	29.00		
36.15	30.00		

The above is data for one of the runs in which a complete profile was mapped. Vertical distances are recorded in centimeters and horizontal distances are recorded in inches. Bottom elevation was 15.75 cm.

... ..

TABLE VIII
SAMPLE DATA SHEET (RUN 41b)

Manometer 1.77 feet, $\alpha = 2^\circ$.

Foil location: vertical 23.09 cm., horizontal 16.40 cm.

<u>VERTICAL (cm.)</u>	<u>HORIZONTAL (in.)</u>	
35.22	11.00	Max. (Vert. 33.92 cm. (Hori. 40.40 in.)
35.22	13.00	
35.22	15.00	
35.01	17.00	Min. (Vert. 35.82 cm. (Hori. 48.80 in.)
34.64	19.00	
34.28	21.00	
34.11	23.00	
34.44	25.00	
34.95	27.00	
35.58	29.00	
35.95	31.00	
35.80	33.00	
35.45	35.00	

The above table is data for one of the runs of the series in which the transient was to be studied and the amplitude was to be noted.

TABLE 1. - 1110 - 1111

TABLE 1. - 1110 - 1111
 TABLE 1. - 1110 - 1111

TABLE 1. - 1110 - 1111	TABLE 1. - 1110 - 1111
TABLE 1. - 1110 - 1111	TABLE 1. - 1110 - 1111
TABLE 1. - 1110 - 1111	TABLE 1. - 1110 - 1111
TABLE 1. - 1110 - 1111	TABLE 1. - 1110 - 1111
TABLE 1. - 1110 - 1111	TABLE 1. - 1110 - 1111
TABLE 1. - 1110 - 1111	TABLE 1. - 1110 - 1111
TABLE 1. - 1110 - 1111	TABLE 1. - 1110 - 1111
TABLE 1. - 1110 - 1111	TABLE 1. - 1110 - 1111
TABLE 1. - 1110 - 1111	TABLE 1. - 1110 - 1111
TABLE 1. - 1110 - 1111	TABLE 1. - 1110 - 1111
TABLE 1. - 1110 - 1111	TABLE 1. - 1110 - 1111

TABLE 1. - 1110 - 1111
 TABLE 1. - 1110 - 1111

TABLE IX

SAMPLE DATA SHEET (RUN 4ba)

Manometer 1.015 feet, $\alpha = 3^\circ$, $d_0 = 40.25$ cm.
 Foil location: vertical 32.68 cm.

Max.	40.75 cm.
Min.	39.60 cm.
Max.	40.64 cm.
Min.	39.69 cm.
Max.	40.84 cm.
Min.	39.59 cm.

The above is data from a run of a series in which amplitude only was studied.

REMARKS

WATER LEVEL 1000

△△△△△

... $\sigma = 30$...

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

The above is also true of a number of other countries with

malloche 525

APPENDIX C

SAMPLE INTERMEDIATE PLOTS



THE
UNITED STATES OF AMERICA

DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

WATER RIGHTS
DIVISION
SALT LAKE CITY, UTAH

TO THE
LAND OFFICE

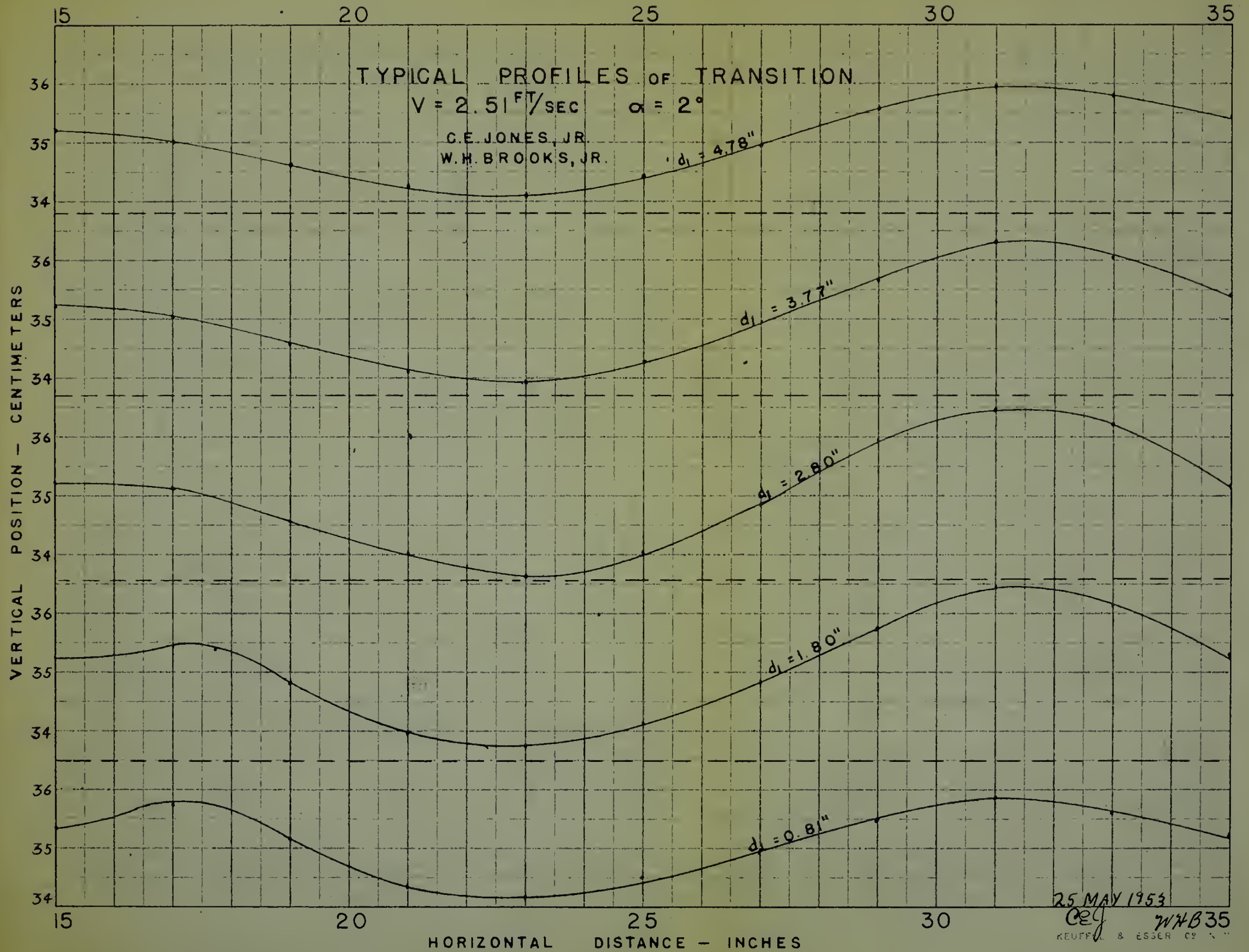
FOR THE
PURPOSE OF

RECORDING

APPENDIX C

SALT LAKE COUNTY, UTAH

FIGURE XV



25 MAY 1953

C.E.J. W.H.B.35
 KEUFFEL & ESSER CO. N.Y.

THE
UNITED STATES DEPARTMENT OF AGRICULTURE

OFFICE OF THE CHIEF OF BUREAU OF PLANT INDUSTRY
WASHINGTON, D. C.

1	2	3
4	5	6
7	8	9
10	11	12
13	14	15
16	17	18
19	20	21
22	23	24
25	26	27
28	29	30
31	32	33
34	35	36
37	38	39
40	41	42
43	44	45
46	47	48
49	50	51
52	53	54
55	56	57
58	59	60
61	62	63
64	65	66
67	68	69
70	71	72
73	74	75
76	77	78
79	80	81
82	83	84
85	86	87
88	89	90
91	92	93
94	95	96
97	98	99
100	101	102

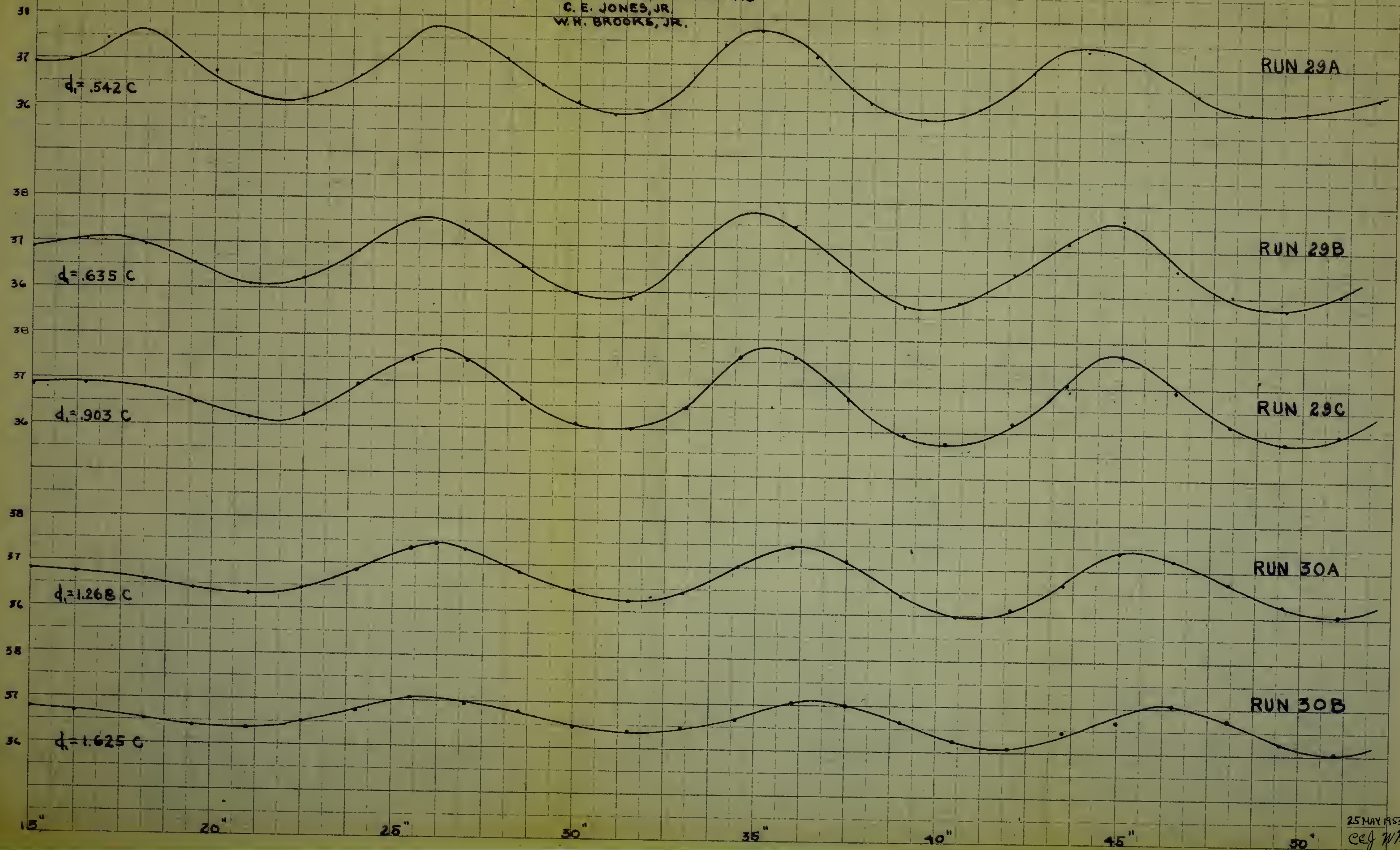
By _____
Special Agent in Charge

APPROVED

SPECIAL AGENT IN CHARGE

FIGURE XVI

PLOT OF WAVE PROFILES
 $\alpha = 0^\circ$ $V = 1.98$ FT/SEC.
 HORI. DISTANCE IN INCHES
 VERT. DISTANCE IN CENTIMETERS
 C. E. JONES, JR.
 W. H. BROOKS, JR.





APPENDIX D
LITERATURE CITATIONS

PLATE 10
PLATE 10

LITERATURE CITATIONS

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3. Scarborough, J. B., "Numerical Mathematical Analysis", Johns Hopkins Press. Pages 443-445.
4. Lamb, H., "Hydrodynamics" (Sixth Edition), Dover Publications. Pages 402, 404-415.
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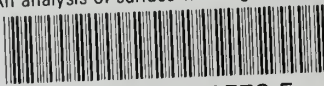
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